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A USER'S MANUAL FOR: ELECTROMAGNETIC SURFACE PATCH CODE (ESP).(U)
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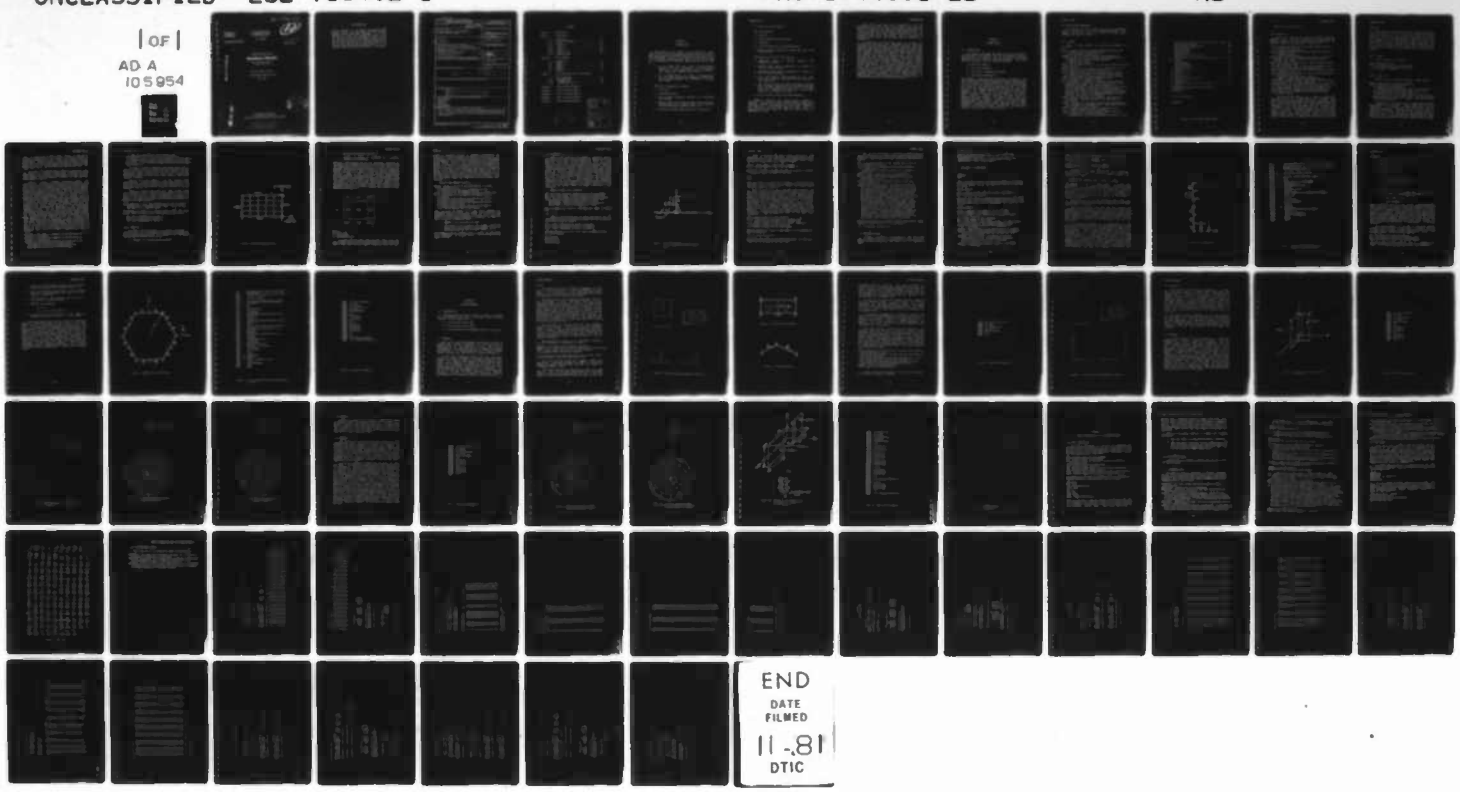

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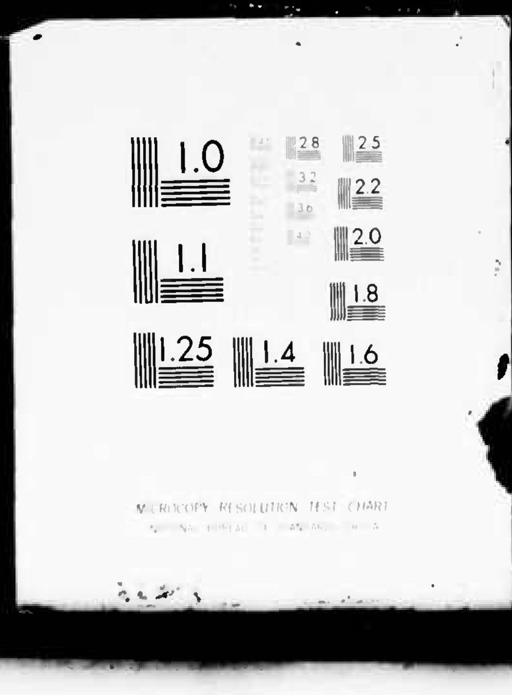

PROGRAM INPUT

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The Ohio State University

A USER'S MANUAL FOR:
ELECTROMAGNETIC SURFACE
PATCH CODE (ESP)

E.H. Newman

LEVEL II

AD A105954

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ElectroScience Laboratory

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Columbus, Ohio 43212

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report is a code manual for the Electromagnetic Surface Patch Code (ESP). The code can find the radiation and scattering from geometries consisting of rectangular plates, thin wires, wire/plate junctions and plate/plate junctions.

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CHAPTER 1

INTRODUCTION

The purpose of this report is to provide a user's manual for "The Electromagnetic Surface Patch Code" (ESP). This code implements a moment method solution for thin-wires and rectangular plates. This report will describe the use of the ESP code, rather than the details of the code itself or it's theoretical background. These details can be found in:

1. E. H. Newman and D. M. Pozar, "Electromagnetic modeling of of composite wire and surface geometries," IEEE Trans. Antennas and Propagat., vol. AP-26, pp. 784-789, Nov. 1978.

2. E. H. Newman and D. M. Pozar, "Considerations for efficient wire/surface modeling," IEEE Trans. Antennas and Propagat., vol. AP-28, pp. 121-125, Jan. 1980.

The code is capable of treating:

1. thin wires
2. rectagular plates
3. wire to plate junctions atleast 0.1 wavelengths from an edge
4. plate to plate junctions, including several plates intersecting at a common edge; the sides of intersecting plates need not "line up"
5. excitation by delta-gap generator or plane wave.

6. open or closed surfaces

The code computes:

1. currents
2. input impedance and admittance
3. efficiency
4. far-zone patterns (both polarizations)
5. back or bistatic scattering (theta, phi and cross polarization)

Some special features of the code are:

1. simplified input of problem geometry and computation desired
2. overlap modes enforce continuity of current at plate to plate junctions
3. attachment modes enforce continuity of current at wire to plate junctions
4. a wire may contact a plate anywhere in it's area, i.e., the junction need not have any relation to the plate modes
5. for a series of problems where the geometry changes only slightly from one run to the next, only that portion of the impedance matrix which has changed need be computed from one run to the next (resulting in a savings in time)
6. plots of patterns and wire/plate geometry.

Chapter 2 describes the program input. Chapter 3 describes the program output and contains several design examples. Chapter 3 describes the various array dimensions, and what to do if dimensions must be changed. Chapter 3 also describes various files used by the code. A description of the magnetic tape, on which the code is supplied, is given.

This manual and the code it describes are not necessarily in final form. For example the author has obtained solutions to the problem of wires attached near the edge of a plate and to treating nonrectangular plates. It is anticipated, that in the future, these features will be integrated into the code. Another possibilitie for a new feature includes a flat lossy earth. Also, as feedback is obtained from users, the code may change to reflect their suggestions.

A considerable effort has been made to validate the accuracy of the ESP code. Computed results have been checked against measurements and other solutions (wire-grid solutions and high frequency solutions such the geometrical theory of diffraction). However, experience has shown that with complex codes there is always a combination of inputs or a geometry for which the code will fail. When writing and testing the code we generally had in mind the wires representing antennas and the plates representing support structure or other scattering obstacles. We have not tested such things as wires forming transmission lines, plates forming waveguides (we have successfully modeled a cavity antenna with plates), or two closely spaced plates forming a thick plate. We have modeled microstrip antennas with plates, but this required a special purpose code. The point is that the results of this or any other code should not be trusted absolutely. Atleast some of the results should be compared with measurements or other computations on a similar problem. This is especially true if the problem is considerably different from those previously run.

CHAPTER 2

PROGRAM INPUT

2.1 INTRODUCTION

This chapter describes the input to the Electromagnetic Surface Patch Code (ESP). That is, this chapter will give the method for describing to the program the problem geometry and the type of computation desired. This input data can be broken into four parts as follows:

1. the wire geometry

2. the plate geometry

3. the type of computation desired

4. miscellanous parameters.

Two methods of inputting this information are employed. The wire geometry and a description of wire/plate junctions are input by the user writing a FORTRAN subroutine called WGEOM, or by an input file (logical unit 5). All other quantities are read in via the input file (logical unit 5). To code user's who are used to inputting all data via an input file, the use of a FORTRAN subroutine to describe the wire geometry may seem like an unnecessary complication. However, we have found that it often results in an easier, more versatile, faster, and more reliable method of inputting the wire geometry. The reason is that the wires usually represent antennas or other structures which have geometrically a very regular, periodic, or simple shape, expressable in mathematical terms. Good examples are linear monopoles or dipoles, helix or loop antennas, log periodic antennas, and antenna arrays. In any case, the user has a choice of an input file or the subroutine.

2.2 INPUT READ STATEMENTS

The details of the input data will now be presented. Figure 1 shows the 15 input or READ statements. The * implies free format read. DO LOOP's are shown which indicate the order of execution.

2.2.1 READ 1

READ 1 inputs several run control parameters as follows:

NGO = 0 implies input and printout geometry and then stop (i.e., do not perform computations).
= 1 implies execute entire run.
NPRINT = 0 implies printout certain input parameters (frequency, wire radius, integration parameters, etc.).
= 1 implies print wire and plate geometry.
= 2 implies print both.
= 3 implies print neither.
NRUNS = the number of runs, i.e., the limit of the DO 700 loop in Figure 1.
NWGS = for each run, the number of wire geometries, i.e., the limit of the DO 600 loop in Figure 1.
IWR = 0 implies do not print solution or current vector.
= 1 implies print solution or current vector, as well as detailed geometry for wire and plate mode locations.
IWRZT = 0 implies do not print impedance matrix.
= 1 implies print impedance matrix.
INT = the number of Simpson rule intervals for numerical integrations on wire modes. Typically chosen as 4 and always an even number. If INT = 0 expressions involving exponential integrals are used for wire to wire to wire impedances. These closed form expressions require more computer time than a numerical integration with INT = 4. Self or overlapping impedances are always done with the closed form expressions, which are more accurate than numerical integration.
INTP = number of intervals for numerical integration on plate modes. Typically chosen as 10, and always an even number.
INTD = the number of intervals for numerical integration on disk component of attachment modes. Typically chosen as 18, and always an even number.
INWR = 0 implies geometry does not contain any wires.
= 1 implies geometry does contain wires.
IRGM = 0 implies that the wire and attachment geometry is to be generated in subroutine WGEOM.
= 1 implies that the wire and attachment geometry is to be

```
      READ(5,*)NGO,NPRINT,NRUNS,NWGS,IWR,IWRZT,INT,INTP,INTD,INWR,IRGM     (1)
      READ(5,*)IFE,IPFE,NDFE,PHFE                                          (2)
      READ(5,*)IFA,IPFA,NDFA,THFA                                          (3)
      READ(5,*)ISE,IPSE,NDSE,PHSE,THIN,PHIN                                (4)
      READ(5,*)ISA,IPSA,NDSA,THSA                                          (5)
      DO700NRUN=1,NRUNS
      READ(5,*)FMC,CMM,A                                                   (6)
      READ(5,*) NPLTS,IOVL                                                 (7)
      IF(NPLTS.EQ.0)GOTO460
      DO420NPL=1,NPLTS
      READ(5,*)NM12N(NPL),NM23N(NPL),IPN(NPL)                              (8)
      DO420NCNR=1,3
      READ(5,*)PCN(1,NCNR,NPL),PCN(2,NCNR,NPL),PCN(3,NCNR,NPL)             (9)
420   CONTINUE
460   CONTINUE
      DO 600 NWG=1,NWGS
      READ(5,*)IWRZM,IRDZM                                                 (10)
      IF(INWR.EQ.0)GOTO2773
      IF(IRGM.EQ.0)GOTO2800
      READ(5,*)NM,NP,NAT,NFPT                                              (11)
      DO2810I=1,NP
      READ(5,*)X(I),Y(I),Z(I)                                              (12)
 2810 CONTINUE
      DO2820I=1,NM
      READ(5,*)IA(I),IB(I)                                                 (13)
 2820 CONTINUE
      DO2830I=1,NFPT
      IF(NFPT.GE.1)READ(5,*)IFN,IAB,VLG,ZL                                 (14)
 2830 CONTINUE
      IF(NAT.EQ.0)GOTO2850
      DO2840I=1,NAT
      READ(5,*)NAS,IAB,NPLA(I),VGA(I),ZLDA(I),BDSK(I)                      (15)
 2840 CONTINUE
      GOTO2850
 2800 CALLWGEOM(IA,IB,X,Y,Z,NM,NP,NAT,NSA,NPLA,VGA,BDSK,
     2ZLDA,NWG,VG,ZLD,KV)
 2850 CONTINUE
 2773 CONTINUE
                   .
                   .
                   .
 *** MAIN BODY OF PROGRAM ***
                   .
                   .
                   .
  600 CONTINUE
  700 CONTINUE
```

Figure 1 - The 15 input or READ statements

read in via the input file.

2.2.2 READ'S 2-5

READ's 2-5 specify the far-zone patterns desired. READ's 2 and 3 are for elevation and azimuth radiation patterns, respectivily, while 4 and 5 are for elevation and azimuth scattering, respectively. Specifically:

IFE = 0 implies do not compute far-zone radiation pattern in the elevation plane.
= 1 implies compute pattern.
IPFE = 0 implies do not plot far-zone radiation pattern in the elevation plane.
= 1 implies plot pattern.
NDFE = angle increment in degrees for far-zone radiation pattern in the elevation plane (should be evenly divisible into 360).
PHFE = phi angle in degrees for far zone radiation pattern in the elevation plane.
IFA, IPFA, and NDFA = same as IFE, IPFE, and NDFE for far-zone radiation pattern in the azimuth plane.
THFA = theta angle in degrees for far-zone radiation pattern in the azimuth plane.
ISE = 0 implies do not compute far-zone scattering pattern in the elevation plane
= 1 implies compute backscatter pattern
= 2 implies compute bistatic scatter pattern.
IPSE, NDSE, and PHSE = same as IPFE, NDFE, and PHFE except that they are for far zone scattering.
THIN and PHIN = theta and phi direction of the incident wave for all bistatic scattering (i.e., ISE or ISA = 2).
ISA, IPSA, and NDSA = same as ISE, IPSE, and NDSE except that they are for scattering in the azimuth plane.
THSA = theta angle in degrees for scattering pattern in the azimuth plane.

If ISE or ISA are set to -1 or -2, then it will have the same effect as setting them to 1 or 2, respectively, except that an incident image wave will be included. That is, if a theta polarized wave is incident from (theta,phi), then a theta polarized wave from (pi-theta,phi) will be included. If a phi polarized wave is incident from (theta,phi), then a -phi polarized wave from (pi-theta,phi) will be included. The image plane is the xy plane. This option is of use in treating problems over an infinite ground plane using image theory. Note that this option automatically inserts the image wave, however, it is the user's responsibility to insert the image of the wire/plate

geometry.

Note that one can not mix patterns on the same run. Thus, on the same run, one can not get a radiation pattern and a scattering pattern, or a back and bistatic scattering pattern. Also it is not possible, on the same run, to get two or more of the same pattern type. Thus, one may obtain an azimuth and a elevation plane pattern on the same run, but not two azimuth or two elevation plane patterns. For the user who wishes a combination of patterns not permitted on a single run, READ 10 will permit any combination of patterns to be effeciently obtained on several successive runs.

2.2.3 READ 6

READ 6 inputs the following:

FMC = frequency in MHZ.
CMM = wire conductivity in megamho/meter.
   = -1.0 implies infinite conductivity.
A = wire radius in meters.

2.2.4 READ'S 7-9

READ's 7-9 input the plate geometry. READ 7 inputs:

NPLTS = the number of rectangular plates.
IOVL = indicator for overlap modes.
   = 0 implies no overlap modes.
   = 1 implies insert overlap modes only if one (or both) of the contacting plates has a current polarization mode perpendicular to the common edge.
   = 2 implies insert overlap modes whenever two or more plates intersect along a common edge. The corners of the intersecting plates need not coincide. See Design Example V in the next section.

One feature of the code is that it automatically checks for plates which intersect along a common edge. Surface patch dipole, or overlap, or hinge modes can then be inserted to enforce continuity of the transverse current across the common edge. Inserting these overlap modes is equivalent to saying that the two (or more) plates are in physical contact. Not inserting the overlap modes is saying that the two (or more) plates are close but do not touch. The parameter IOVL permits the user to select which of these

cases is appropriate to his problem. Plates are considered to have a common edge if the edges are within TOUCH of coinciding. TOUCH is set in the main program at 0.001 wavelengths. When M plates are detected as having a common edge, M-1 sets of overlap modes are inserted (assuming IOVL was properly set). For most applications the user will set IOVL = 2.

For each of the NPLTS plates, READ 8 is executed once and READ 9 is executed three times. Together these two READ's specify the location, segmentation, and mode current polarization on a given plate. If NPLTS = 0, then the code skips READ's 8 and 9.

Figure 2 shows a typical rectangular plate. The location of the plate is defined by the coordinates of any three consecutive (clockwise or counterclockwise) corners of the plate. For the purpose of placing surface patch dipole modes on the plate, the plate must be divided into smaller rectangular segments or monopoles. The user specifies the number of segments from point 1 to point 2 (= 5 in Figure 2) and the number of segments from point 2 to point 3 (= 4 in Figure 2). In choosing segment size the general rule is that the segment length or width should not exceed a quarter wavelength. Our experience indicates that a segment size of a quarter wavelength yields reasonable results for most applications. If more accuracy is required, one can try reducing the segment size to 0.2 or 0.15 wavelengths. However, this is as small a segmentation that one would ordinarily use. If one uses the quarter wavelength segments, then there will be 12 surface patch dipole modes per square wavelength of surface per current polarization, or, 24 total modes per square wavelength of surface. If the user specifies NM12 segments in the 1 to 2 direction and NM23 segments in the 2 to 3 direction, then (assuming the user has specified two orthogonal current polarizations on this plate) there will be NM23*(NM12-1) modes polarized in the 1 to 2 direction, and NM12*(NM23-1) modes polarized in the 2 to 3 direction. The plate in Figure 2 would have 16 modes in the 1 to 2 direction and 15 modes in the 2 to 3 direction, for a total of 31 modes. Specifically, READ 8 inputs:

NM12(NPL) = the number of segments on the NPL plate in the 1 to 2 direction.

NM23(NPL) = the number of segments on the NPL plate in the 2 to 3 direction.

IPN(NPL) = 1 implies place modes on the NPL plate with polarization in the 1 to 2 direction only.
= 2 implies place modes on the NPL plate with polarization in the 2 to 3 direction only.

= 3 implies place modes on the NPL plate with polarization in the 1 to 2 and 2 to 3 direction.
= 0 implies place no modes on the NPL plate. If this option is chosen, then the only way that current can flow on the NPL plate is if it contacts another plate and overlap modes are placed on it.

The above method for specifying the modal layout on a plate is ideal in that it gives the user virtually complete control of, and yet divorces him from the details of the overlapping dipole mode layout. Thus, even if a plate has hundreds of modes, the user need only specify the three integers in READ 8.

Usually one sets IPN(NPL) = 3 to obtain both polarizations. However, there are cases where the user may know that one of the polarizations is not significant. In this case, one can save computer time and storage by setting IPN(NPL) = 1 or 2.

READ 9 is executed three times for each plate, each time inputting three floatting point numbers. The first time one inputs the x, y, and z coordinates in meters of point 1 of the plate. Next one inputs the coordinates of point 2, and finally one inputs the coordinates of point 3. Specifically READ 9 inputs:

PCN(I,NCNR,NPL) = the I-th coordinate (I = 1,2,3 for x,y,z respectively) of the NCNR corner (NCNR = 1,2,3) of the NPL (NPL = 1,2,...NPLTS) plate.

As noted above, READ 9 is executed three times for each plate. Thus, for each plate, one inputs the three lines:

the x,y,z coordinates of corner 1
the x,y,z coordinates of corner 2
the x,y,z coordinates of corner 3.

2.2.5 READ 10

At times a user may wish to run several problems in succession for which the impedance matrix does not change at all or changes only slightly. For example, the impedance matrix will not change at all if one:

1. changes the far-zone pattern desired

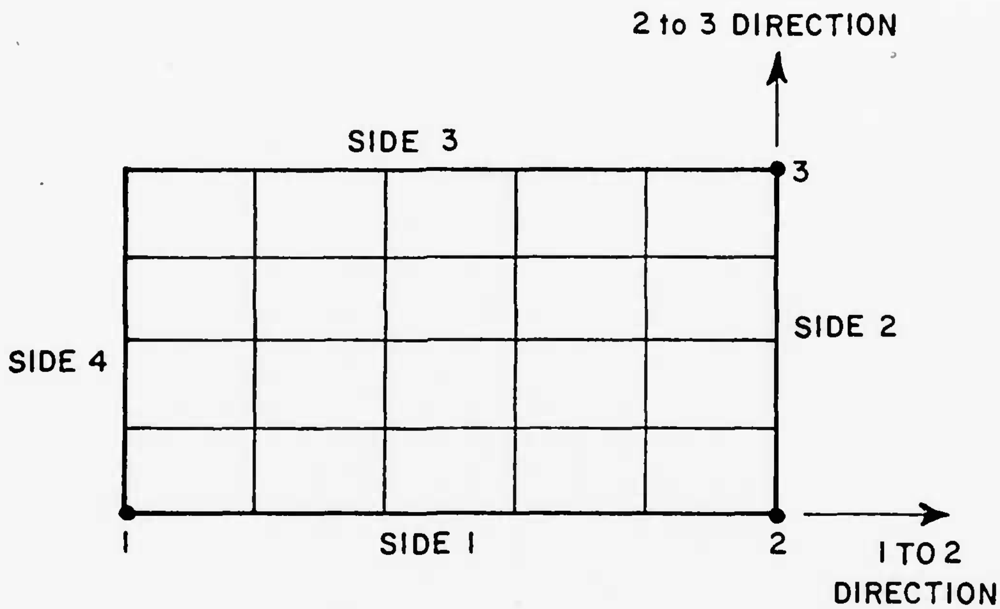


Figure 2 - A typical rectangular plate

2. changes the voltage excitation

3. changes the angle of incidence in a bistatic scattering calculation.

Obviosly in these cases it would be extremely wasteful to recompute the impedance matrix. At other times the geometry may change only slightly from one run to the next. For example, suppose one is faced with the problem of locating a monopole on a ship in order to achieve a desired impedance and/or pattern. In order to solve this problem one would construct a model of the ship from several intersecting plates, possibly requiring hundreds of surface patch modes. The monopole would be modeled by one or two wire modes, and one attachment mode would be required where the monopole contacted a plate. The user would then analyze this configuration for many monopole locations, looking for the one which best met his design goals. The moment method impedance matrix for this (or in general any) problem can be symbolically shown as

$$[Z] = \left[\begin{array}{c|c|c} W/W & W/P & W/A \\ \hline \\ \\ P/W & P/P & P/A \\ \\ \\ \hline A/W & A/P & A/A \end{array}\right]$$

where:
W = wire mode
P = plate mode
A = attachment mode.

In showing [Z], we have indicated that there are, in this example, many more plate modes than wire and attachment modes. Note that only the lower triangular part of the

symmetric impedance matrix is computed and stored. the point is that as the monopole is moved the P/P block [Z] is unchanged, since the number and location of the plate modes do not change. Only the blocks involving wire or attachment modes change. Thus a very considerable time saving will result if on the first run the entire matrix is computed and stored (on a disk). On subsequent runs the stored matrix is read in, and only those blocks involving wire or attachment modes (i.e., the lower triangular part except for the P/P block) are recomputed. It is important to note that on a problem such as the monopole on a ship considered here the P/P block would involve the majority of the computer time. By specifying IWRZM and IRDZM one can easily obtain this savings.

Specifically READ 10 inputs:

IWRZM = indicator to write impedance matrix on a disk file, logical unit 1.
- = 0 implies do not write out impedance matrix.
- = 1 implies write out impedance matrix.

IRDZM = indicator to read impedance matrix from disk file.
- = 0 implies do not read matrix and compute entire new matrix.
- = 1 implies read in matrix and compute new matrix except for the W/W and A/A block.
- = 2 implies read in matrix and compute new matrix except for the P/P block.
- = 3 implies read in matrix and use as new matrix, i.e., do not compute entire new matrix.

Thus, one would set IRDZM = 2 if the plate geometry is unchanged from the last run, IRDZM = 1 if the wire and attachment geometry is unchanged from the last run, and IRDZM = 3 if the entire geometry is unchanged. If IRDZM is set > 0 then it is essential that:

1. IWRZM = 1 on a previous run and

2. the number of wire modes, the number of plate modes, and the number of attachment modes is unchanged from the the run where IWRZM = 1.

The impedance matrix is read from or written to the disk file ZMAT.DAT.1 on logical unit 1. It is an unformatted READ or WRITE.

2.2.6 READ'S 11-15

READ's 11-15 input the wire geometry, including loads, generators, and wire to plate attachments. READ's 11-15 are executed only if INWR = 1 (see READ 1) and IRGM = 1 (see READ 1). The wire geometry consists of a series of interconnected straight wire segments or monopoles. Segment lengths should not exceed a quarter wavelength, and no two intersecting segments should form an acute angle less than about 30 degrees. Also, a single isolated segment is not permitted. The wire geometry input will be described with the aid of the example shown in Figure 3. The structure consists of a T shaped wire with one load and one generator. The wire consists of a number of points, shown as heavy black dots in Figure 3, and segments. An arbitrary numbering scheme is established for the points and segments. In Figure 3 the point numbers are shown adjacent to the dots, and the segment numbers are shown circled next to the segments.

READ 11 inputs the following:

NM = the total number of segments on the wire structure.
NP = the total number of points on the wire structure.
NAT = the total number of wire to plate attachment points.
NFPT = the total number of feed locations in the wire, specifically excluding feeds at wire to plate attachments. Here a feed location is a location at which there is either a generator or a load.

For the geometry of Figure 3, the input for READ 11 would be:

3 4 1 1 .

READ 12 requires NP lines of input, specifying on the I-th line the x,y,z coordinates in meters of the I-th point. Specifically READ 12 inputs:

X(I) = the x coordinate of point I in meters.
Y(I) = the y coordinate of point I in meters.
Z(I) = the z coordinate of point I in meters.

For the geometry of Figure 3 the input for READ 12 would be the NP = 4 lines:

```
0.0 0.0 0.0
0.0 0.0 0.25
0.0 0.0 0.5
-0.3 0.0 0.25  .
```

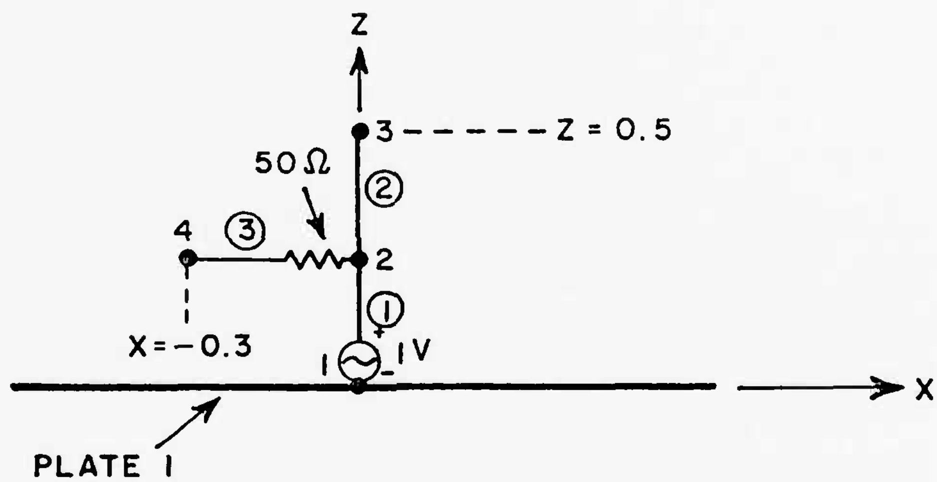


Figure 3 - A wire geometry showing points, segments, a load, a generator, and an attachment point.

READ 13 requires NM input lines, specifying the endpoints of the NM segments. Each segment has two end points denoted A and B. It is arbitrary which end the user selects as A and which as B. READ 13 inputs:

IA(I) = point number of the A end of segment I.
IB(I) = point number of the B end of segment I.

Arbitrarily choosing the smaller point as endpoint A, the NM = 3 lines of input for READ 13 would be:

```
1 2
2 3
2 4
```

Note that there is no limit to the number of wires which can intersect at a given point (except the acute angle limitation described above).

READ 14 inputs, for each of the NFPT feed locations in the wire, the feed location and the complex value of the generator and load at that location. In this code we always think of generators and loads as being inserted into segments, either by point A or by point B of the segment. We do not think of feeds as being at a point in the wire. For example, for the geometry of Figure 3, it is not sufficient to say that the 50 ohm load is "at point 2". There are three locations (although physically close, electrically very different) which could be taken as "at point 2". They are by point B of segment 1, by point A of segment 2, or (in this case the correct choice) by point A of segment 3. READ 14 inputs for each of the NFPT feed locations:

IFM = segment number of feed location.
IAB = 0 implies feed is by point A of segment IFM.
   = 1 implies feed is by point B of segment IFM.
VLG = complex voltage of generator (volts). Note the polarity is from point A to point B.
ZL = complex impedance of the load (ohms).

For the geometry of Figure 3, the NFPT = 1 line of input for READ 14 would be:

```
3 0 (0.0,0.0) (50.0,0.0)
```

Note that since there is no voltage generator at the wire feed location we specify zero for VLG.

READ 15 specifies the wire to plate attachments and the complex values of the generators and loads at the attachment locations. Specifically, for each of the NAT attachments we input:

NAS = the segment number of the segment which contacts or attachs to a plate.

IAB = 0 implies the attachment point is by endpoint A of segment NAS.
= 1 implies the attachment point is by endpoint B of segment NAS.

NPLA(I) = plate number for the I-th attachment.

VGA(I) = complex generator voltage (volts) at I-th attachment. Note that the polarity is minus at the attachment point.

ZLDA(I) = complex load impedance (ohms) at the I-th attachment point.

BDSK(I) = outer disk radius in meters to be used for the I-th attachment mode. The disk is a circle in the plane of the NPLA(I) plate and centered at the I-th attachment point. Two considerations dictate the choice of the disk radius. First, experience has shown that reasonably accurate impedance and patterns can be obtained with disk radii between 0.1 and 0.25 wavelengths. A good average choice is 0.2 wavelengths. Second, the disk must be entirely within the boundaries of the NPLA(I) plate. Thus, if the minimum distance from the attachment point to a side of the plate is d, then BDSK(I) must be chosen less than d. If d < 0.1 wavelengths, then we must violate the first condition. Choosing BDSK(I) < 0.1 wavelengths will result in inaccurate input impedance, but probably reasonably accurate far-zone patterns. Thus we say that attachment points must be atleast 0.1 wavelengths from an edge if accurate input impedance data is required.

Assuming a frequency of 300 MHZ (1 meter wavelength), READ 15 would require the NAT = 1 line of input:

1 0 1 (1.0,0.0) (0.0,0.0) 0.2 .

2.3 SUBROUTINE WGEOM

If IRGM = 0 and INWR = 1 (see READ 1), then the wire and attachment geometry will be specified by the subroutine WGEOM, written by the user, and which has the following form:

PROGRAM INPUT

```
 SUBROUTINE WGEOM(IA,IB,X,Y,Z,NM,NP,NAT,NSA,NPLA,VGA,
2BDSK,ZLDA,NWG,VG,ZLD WV)
 DIMENSIONIA(1),IB(1),X(1),Y(1),Z(1),NSA(1),NPLA(1),BDSK(1)
 COMPLEXVGA(1),ZLDA(1),VG(1),ZLD(1)
         .         .
         .         .
         .         .
   MAIN BODY OF SUBROUTINE
         .         .
         .         .
         .         .
 RETURN
 END
```

Before describing the use of subroutine WGEOM in more detail we will simply define the inputs and outputs of the CALL statement.

WGEOM INPUTS:

NWG = index of DO 600 loop (see Figure 1 and READ 1).
WV = wavelength in meters.

Note that the inputs are automatically defined in the MAIN program, and are not explicitly defined by the user. They are provided as an aid in writing WGEOM, and need not be used.

WGEOM OUTPUTS:

IA(I) = endpoint A of segment I (1 <= I <= NM).
IB(I) = endpoint B of segment I (1 <= I <= NM).
X(J),Y(J),Z(J) = x,y,z coordinates in meters of point J (1 <= J <= NP).
NM = total number of wire segments.
NP = total number of wire points.
NAT = total number of attachment points, i.e., the number of points at which wire segments contact plates.
NSA(K) = attachment "location" for attachment K (1 <= K <= NAT).
NPLA(K) = plate number for attachment K (1 <= K <= NAT).
VGA(K) = complex voltage generator (volts) at attachment K, positive polarity points up wire and away from plate (1 <= K <= NAT)
BDSK(K) = disk radius for attachment K, typically chosen between 0.1 to 0.25 wavelength, however, disk must not overlap an edge of the plate (1 <= K <= NAT).
ZLDA(K) = complex load impedance (ohms) at attachment K (1 <= K <= NAT).

VG(L) = complex voltage generator (volts) at "location L" in the wire (1 <= L <= 2*NM).
ZLD(L) = complex load impedance (ohms) at "location L" in the wire (1 <= L <= 2*NM).

All of the above outputs must be defined by the user via FORTRAN statements in subroutine WGEOM.

In defining the arrays NSA, VG, and ZLD we referred to a "location" in the wire. This means either by point A or by point B of a segment of the wire structure. Specifically "location L" means:

by point A of segment L if L <= NM
by point B of segment NM-L if NM < L <= 2*NM.

For example , if NM = 8, then NSA(3) = 1 means that attachment 3 is by point A of segment 1. If NM = 8, then NSA(3) = 10 means that attachment 3 is by point B of segment 2. If NM = 8, then VG(5) = (3.0,2.0) means that there is a generator of 3.0 + j2.0 volts by point A of segment 5, polarity from point A to B. If NM = 8, then ZLD(13) = (1.0,-1.0) means that there is a load of 1.0 - j1.0 ohms by point B of segment 5.

Note that only the non-zero entries in VG and ZLD need be defined. The first NAT entries in NSA, NPLA, VGA, BDSK, and ZLDA must be defined.

After writing WGEOM, the user has two choices for including it as part of the code. First one could append a FORTRAN version of WGEOM to the end of the code. This has the disadvantage that the entire code must be compiled each time a change is made to WGEOM. A preferred method would to write WGEOM as a separate file, compile it to form an object file, and link the object file with an object file of the main code.

A was mentioned above it is advantageous to use subroutine WGEOM to describe the wire geometry, rather than the input file, when the wire structure is geometrically very regular. There is no better example of this than a straight wire. Thus, suppose one wishes to study the characteristics of a center fed dipole of various lengths and segmentations. Of course one could set IRGM = 1 in READ 1 and input each new geometry via READ's 11-15. The alternative is to set IRGM = 0 and write a subroutine WGEOM capable of generating the dipole geometry for arbitrary length and segmentation. Figure 4 shows a straight wire alligned with the z-axis, of length H, and divided into NM equal segments. We note the following concerning this

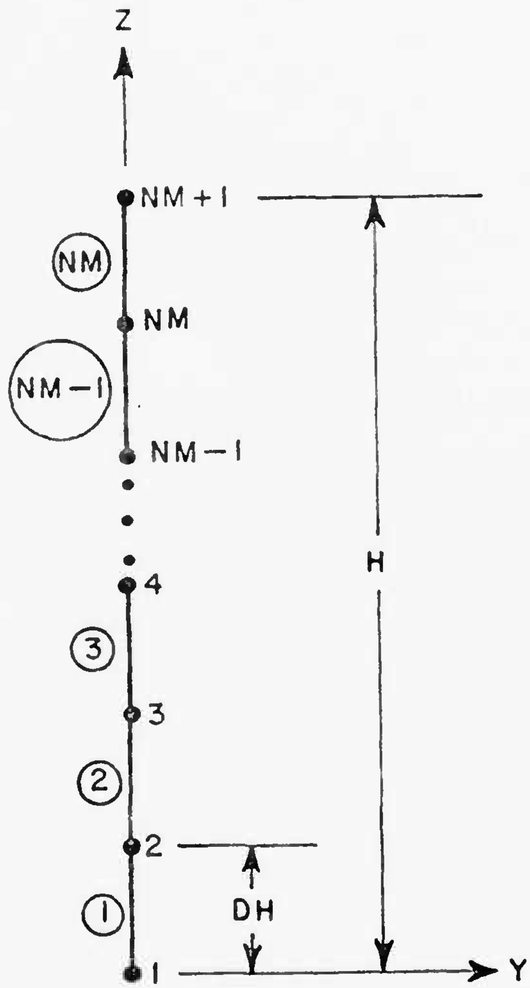


Figure 4 - Segmentation of a straight wire

```
      SUBROUTINEWGEOM(IA,IB,X,Y,Z,NM,NP,NAT,NSA,NPLA,VGA,BDSK,
     2 ZLDA,NWG,VG,ZLD,WV)
      DIMENSIONIA(1),IB(1),X(1),Y(1),Z(1),NSA(1),NPLA(1),BDSK(1)
      COMPLEXVGA(1),ZLDA(1),VG(1),ZLD(1)
C
C     GEOMETRY FOR A CENTER FED DIPOLE.
C
C     SPECIFY H = WIRE LENGTH AND NM = NUMBER OF SEGMENTS.
      H=0.5
      NM=4
C     INSURE THAT NM IS AN EVEN NUMBER.
      NM=2*((NM+1)/2)
C     THE NUMBER OF POINTS IS
      NP=NM+1
C     THE SEGMENT SIZE IS
      DH=H/NM
C     DEFINE COORDINATES OF NP POINTS AND NM SEGMENTS.
      DO100I=1,NP
      X(I)=0.0
      Y(I)=0.0
      Z(I)=(I-1)*DH
      IF(I.EQ.NP)GOTO100
      IA(I)=I
      IB(I)=I+1
  100 CONTINUE
C     DEFINE GENERATOR LOCATION AND VALUE.
      IGN=NM/2+1
      VG(IGN)=(1.0,0.0)
C     INDICATE NO ATTACHMENTS.
      NAT=0
      RETURN
      END
```

Figure 5 - A subroutine WGEOM to describe the center fed dipole of Figure 4.

geometry:

1. The number of points is NP = NM+1 .

2. The segment size is DH = H/NM .

3. The J-th point is at:

   X(J) = 0.0

   Y(J) = 0.0

   Z(J) = (J-1)*DH .

4. The I-th segment has endpoints:

   IA(I) = I

   IB(I) = I+1 .

5. If the dipole is to be center fed then NM must be an even number, and the generator location is:

   IGN = (NM/2)+1 or

   IGN = NM+NM/2 .

Based on the observations, Figure 5 shows a subroutine WGEOM which generates the dipole geometry. COMMENT statements describe the various sections of the subroutine. As shown in Figure 5, WGEOM is set up for an H = 0.5 meter dipole with NM = 4 segments. The advantage of writing subroutine WGEOM is that dipoles of different lengths and segmentations can be obtained by simply changing lines 90 and 100. Note that excluding COMMENT statements, the main body of this particular WGEOM contains only 16 lines. The output for this geometry will be shown in Design Example 2 in the next chapter.

As a second example of writing a subroutine WGEOM, consider the problem of describing a polygon loop of arbitrary radius, number of sides, and maximum segment size in wavelengths. We will use the notation:

R = the loop radius radius in meters.
NS = the number of sides in the polygon loop.
SWX = the maximum segment size in wavelengths.

Figure 6 shows a hexagon loop with NMS = 2 segments per side. For a general polygon loop we note the following:

1. If there are NMS segments per side, then the total number of segments is NM = NMS*NS, and NP = NM.

2. If SL is the length of one side of the polygon, then the number of segments per side is the first integer >= SL/(SWX*WV).

3. The I-th side of the polygon goes from phi = (I-1)*360/NS to I*360/NS degrees.

4. Segment J has endpoints:

   IA(J) = J

   IB(J) = J+1 except IB(NM) = 1 .

5. If the loop is to be fed at phi = 0.0, then the generator location is at IGN = 1 or IGN = 2*NM.

Using these observations, Figure 7 shows a subroutine WGEOM for the polygon loop. It is set for an NS = 6 sided loop of radius R = 0.3 meters and with segments less than SWX = 0.2 wavelengths (regardless of the frequency). By changing lines 100, 110, and 120 one can easily generate the geometry for polygon loops of different radius, number of sides, and maximum segment size in wavelengths. Note that since we specified the maximum segment size in wavelengths, this routine can be used at virtually any frequency with no modification. The routine automatically increases the number of segments as the wavelength decreases (frequency increases) and decreases the number of segments as the wavelength increases (frequency decreases). This frequency independent quality is especially desireable if one is going to analyze the wire geometry over a very broad frequency range.

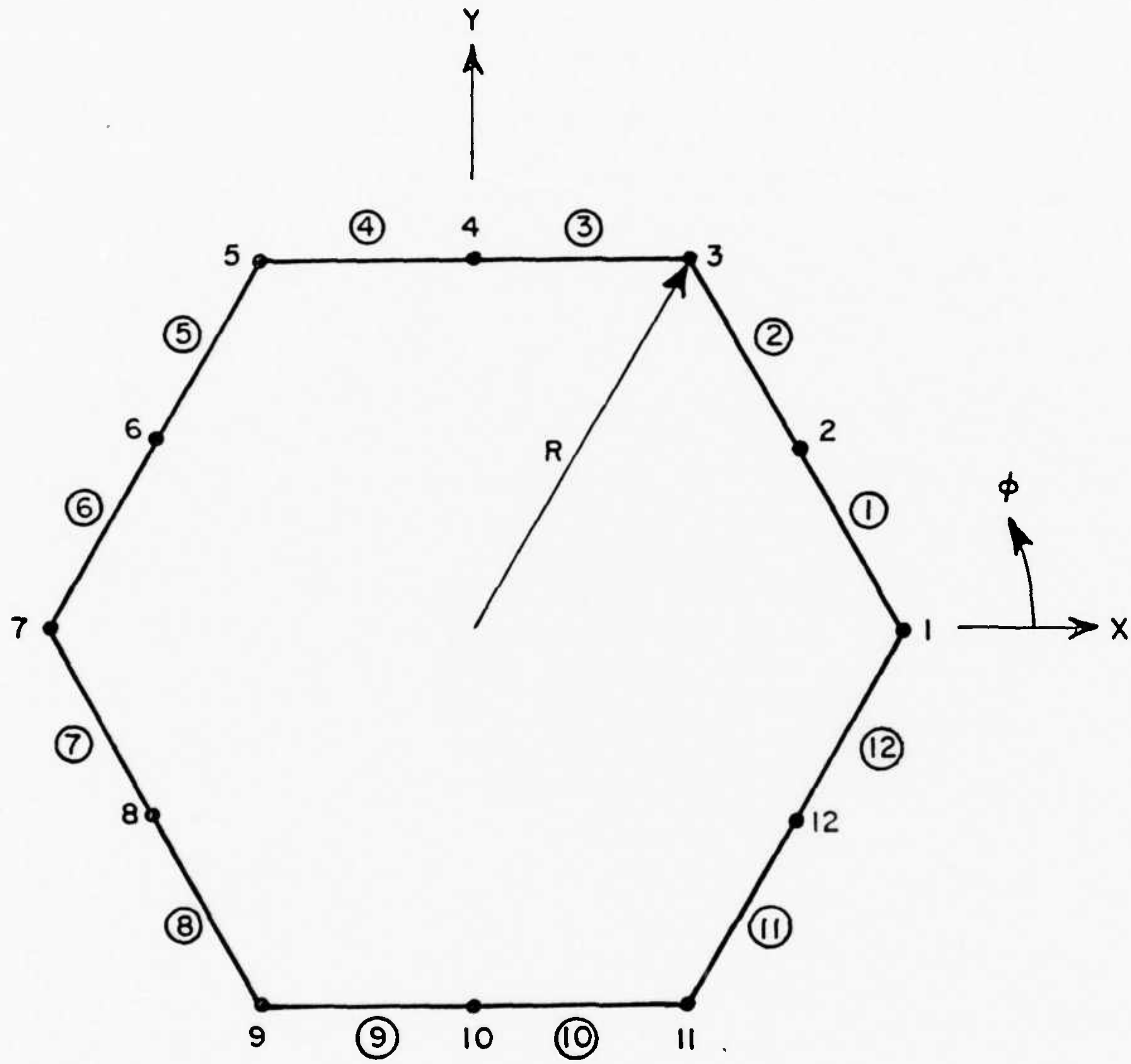


Figure 6 - Segmentation of a hexagon loop

```
      SUBROUTINEWGEOM(IA,IB,X,Y,Z,NM,NP,NAT,NSA,NPLA,VGA,BDSK,
     2 ZLDA,NWG,VG,ZLD,WV)
      DIMENSIONIA(1),IB(1),X(1),Y(1),Z(1),NSA(1),NPLA(1),BDSK(1)
      COMPLEXVGA(1),ZLDA(1),VG(1),ZLD(1)
C
C     GEOMETRY FOR POLYGON LOOP.
C
C     SPECIFY LOOP R = LOOP RADIUS IN METERS, NS = NUMBER OF
C     SIDES IN POLYGON LOOP, AND SWX = MAXIMUM SEGMENT SIZE
C     IN WAVELENGTHS.
      R=0.3
      NS=6
      SWX=0.2
C     FIND SL = SIDE LENGTH.
      PI=4.0*ATAN(1.0)
      DPH=2.0*PI/NS
      SL=2.0*R*SIN(DPH/2.0)
C     FIND NMS = NUMBER OF SEGMENTS PER SIDE AND DSL = THE
C     SEGMENT LENGTH.
      DSL=SWX*WV
      NMS=0.99+SL/DSL
      DSL=SL/NMS
C     FIND NM = THE TOTAL NUMBER OF SEGMENTS AND NP = THE TOTAL
C     NUMBER OF POINTS.
      NM=NS*NMS
      NP=NM
C     DEFINE NMS POINTS AND SEGMENTS ON EACH OF THE NS SIDES.
      DO100I=1,NS
C     THE COORDINATES OF THE FIRST END OF SIDE I IS AT
      PH1=(I-1)*DPH
      X1=R*COS(PH1)
      Y1=R*SIN(PH1)
C     THE COORDINATES OF THE SECOND END OF SIDE I IS AT
      PH2=I*DPH
      X2=R*COS(PH2)
      Y2=R*SIN(PH2)
C     EACH POINT ON SIDE I WILL BE
      DX12=(X2-X1)/NMS
      DY12=(Y2-Y1)/NMS
C     FROM THE LAST POINT ON SIDE I.
      DO200J=1,NMS
C     DEFINE THE K TH POINT AND SEGMENT.
      K=(I-1)*NMS+J
      X(K)=X1+(J-1)*DX12
      Y(K)=Y1+(J-1)*DY12
      Z(K)=0.0
      IA(K)=K
      IB(K)=K+1
      IF(K.EQ.NM)IB(K)=1
  200 CONTINUE
  100 CONTINUE
C     PLACE A 1 VOLT GENERATOR AT THE X AXIS.
      IGN=1
      VG(IGN)=(1.0,0.0)
C     INDICATE NO ATTACHMENTS.
      NAT=0
      RETURN
      END
```

Figure 7 - A subroutine WGEOM to describe the polygon loop of Figure 6.

```
00100   1 2 1 1 1 0 4 10 18 1 1
00200   1 1 3 0.0
00300   0 1 3 90.0
00400   0 1 3 0.0 90.0 0.0
00500   0 1 3 90.0
00600   150.0 38.0 0.001
00700   1 2
00800   4 4 3
00900   -0.5 -0.5 0.0
01000   0.5 -0.5 0.0
01100   0.5 0.5 0.0
01200   0 0
01300   3 4 1 1
01400   0.0 0.0 0.0
01500   0.0 0.0 0.25
01600   0.0 0.0 0.5
01700   -0.3 0.0 0.25
01800   1 2
01900   2 3
02000   2 4
02100   3 0 (0.0,0.0) (50.0,0.0)
02200   1 0 1 (1.0,0.0) (0.0,0.0) 0.4
```

Figure 8 - Input file for Example 1.

CHAPTER 3

DESIGN EXAMPLES

3.1 INTRODUCTION

This section will present several design or example runs illustrating the use of the code. There are three purposes to thes example runs:

1. to illustrate input data

2. to illustrate output data

3. to provide trail or debugging runs for a new user.

3.2 EXAMPLE 1

For the wire and plate geometry of Figure 3 we wish to compute the currents, impedance, and far-zone elevation plane pattern in the plane phi = 0.0. The wire is considered to be in the center of a 1 meter square plate. The frequency is 150 MHZ, and the wire is taken as aluminum (conductivity = 38 megamho/meter) with a radius of 0.001 meter. The input file for this run is shown in Figure 8.

A three view orthagraphic plot of the wire and plate geometry is shown in Figure 9. The code provides this plot if NGO = 0 in READ 1. Edges of the plate are shown as solid lines. Wire segments are shown as solid lines with small circles at the endpoints. A summary of the number of wire, plate, and attachment modes is given, as well as a scale indicating what one inch corresponds to in wavelengths. The plot is provided for two reasons. First it permits the user to see if he has (probably) specified the geometry correctly. Secondly, it provides a permanent pictoral documentation of the geometry, say for later inclusion in a

report.

The output for this run is shown in Appendix I. The file is called OUTFL.DAT on the ElectroScience Lab VAX system. It is logical unit 5. The output begins by listing some of the input quanties such as frequency, wire radius and conductivity, and integration parameters.

Next the geometry of the plates is specified. Shown is the coordinates of three consecutive corners of each rectangular plate, together with the plate segmentation parameters NM12, NM23, and IPN. If IWR = 1 in READ 1, then a detailed printout of the overlapping rectangular surface patch dipole modes is provided. Figure 10 shows a typical surface patch dipole mode, consisting of monopole A and monopole B. Monopole A is defined by points A1, A2, and A3, while monopole B is define by points B1, B2, and B3. By convention the modal current flows A2 to A1 on monopole A, and B1 to B2 on monopole B. If IWR = 1 (see READ 1) the coordinates of points A1, A2, A3, B1, B2, and B3 are printed for each surface patch mode.

The next group of output lists the wire geometry. First the coordinates in meters of the NP points are printed. Next, if IWR = 1, the wire mode layout is printed. Figure 11 shows a typical wire dipole mode going from point I1 to I2 to I3 on segments JA and JB. By convention the direction of positive current is from point I1 to I2 to I3. Next the endpoints and length in meters of each of the NM segments is printed.

The next group of output is th attachment geometry. For each attachment the following is listed:

SEGMENT = wire segment which contacts the plate.
END = 0 or 1 if point IA or IB of the segment contacts the plate.
PLATE = plate number contacted by the wire segment.
B = attachment mode disk radius in meters.

By convention the attachment mode disk current flows inward to the attachment point and then up the wire.

The next printout lists the complex loads and generators. Following this NWR = the number of wire modes, NPLTM = the number of plate modes, and NAT = the number of attachment modes is shown.

The output terminates at this point if NGO = 0 (see READ 1). All of the above output describes the detailed geometry of the problem specified by the user. The user should carefully study these sections to make sure that the

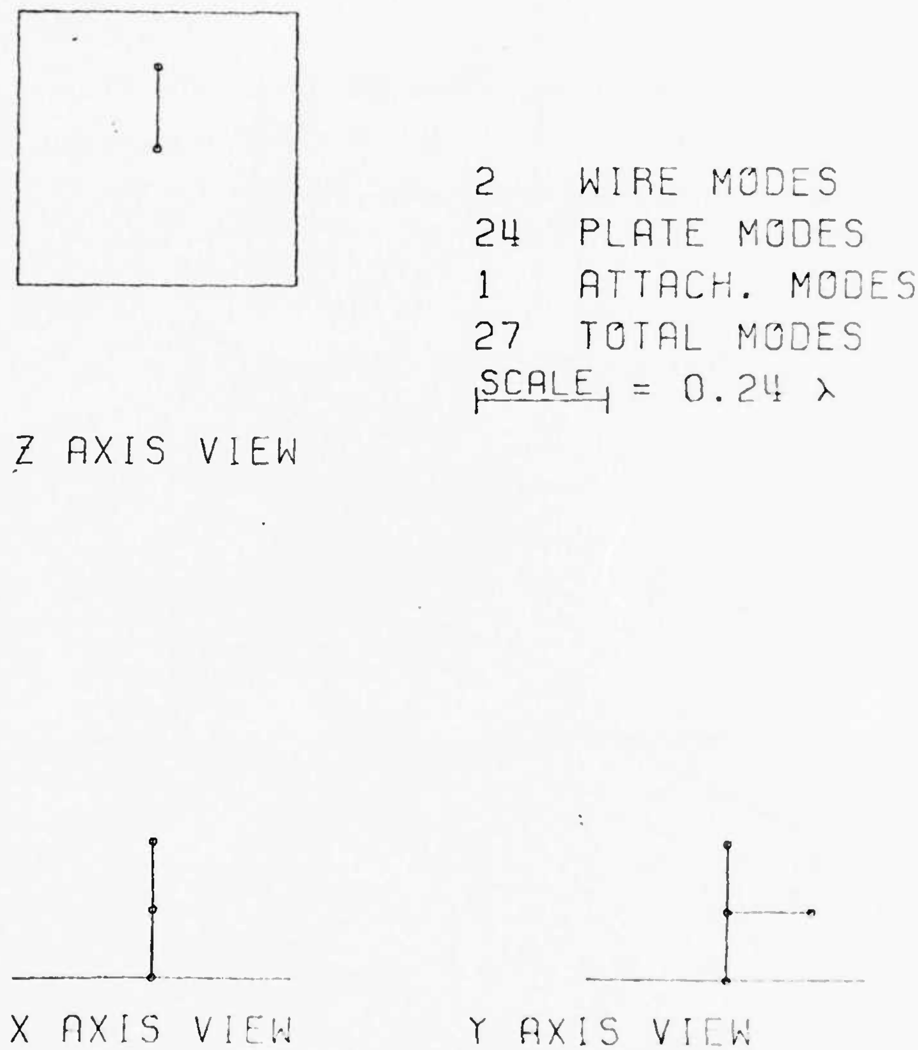


Figure 9 - Three view plot of the geometry of Example 1.

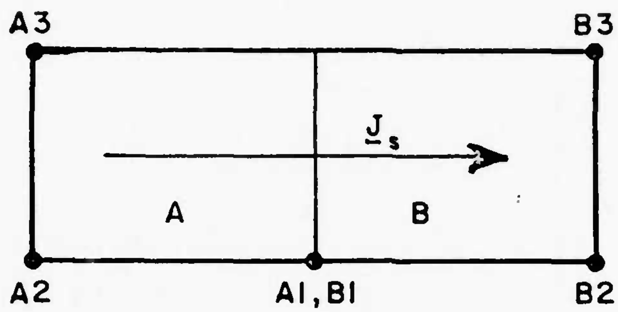


Figure 10 - A surface patch dipole mode.

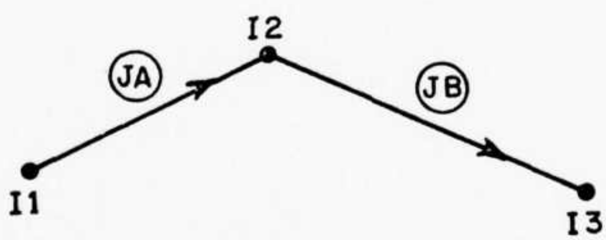


Figure 11 - A wire dipole mode.

wire/plate geometry is correct. The usual procedure for doing this is as follows. When a new geometry is being set up, the initial runs are made with NRUNS = 0 (see READ 1). After studying the printout of the geometry and the orthographic plot of the geometry and being convinced that the geometry is correct, only then is NGO set to 1 to perform the desired computations.

If IWR = 1, the next set of output lists the magnitude of the expansion modes. For each mode, the relative magnitude, the absolute magnitude (amps), the phase (degrees), and the complex magnitude (amps) is tabulated. In this list the first NWR are wire modes, the next NPLTM are surface patch plate modes, and the last NAT modes are attachment modes.

For antenna (as opposed to scattering) problems the input admittance and impedance and radiation efficiency are printed. A wire/plate geometry is considered to be a transmitting antenna if ISE = 0 in READ 4 and ISA = 0 in READ 5. THe values printed for input admittance and impedance are valid if there is only one generator in the wire, and it is 1 +j0 volts.

The final printout is the far-zone patterns. For radiation patterns, the gain in dB for theta and phi polarizations is shown. For scattering patterns, the cross section, sigma/wavelength**2 in dB, for theta and phi and cross polarizations is shown. The phase of the scattered field field is also shown (the incident wave has zero phase at the origon). For backscattering STPM = SPTM, however, both are printed as a check. Due to lack of available data for comparison, the cross polarized data is not as reliable as the principle polarization data. The various quanties are defined as follows:

STTM = scattering cross section with incident and scattered fields theta polarized.
SPPM = scattering cross section with incident and scattered fields phi polarized.
STPM = scattering cross section with incident field theta polarized and scattered field phi polarized.
SPTM = scattering cross section with incident field phi polarized and scattered field theta polarized.
GTHETA = gain for theta polarization.
GPHI = gain for phi polarization.

At the conclusion of each run, the CPU time is printed. In this case is about 117 seconds.

```
00100   1 2 1 1 0 1 4 10 18 1 0
00200   0 1 3 0.0
00300   0 1 3 90.0
00400   0 1 3 0.0 90.0 0.0
00500   0 1 3 90.0
00600   300.0 -1.0 0.001
00700   0 2
00800   0 0
```

Figure 12 - Input file for Example 2.

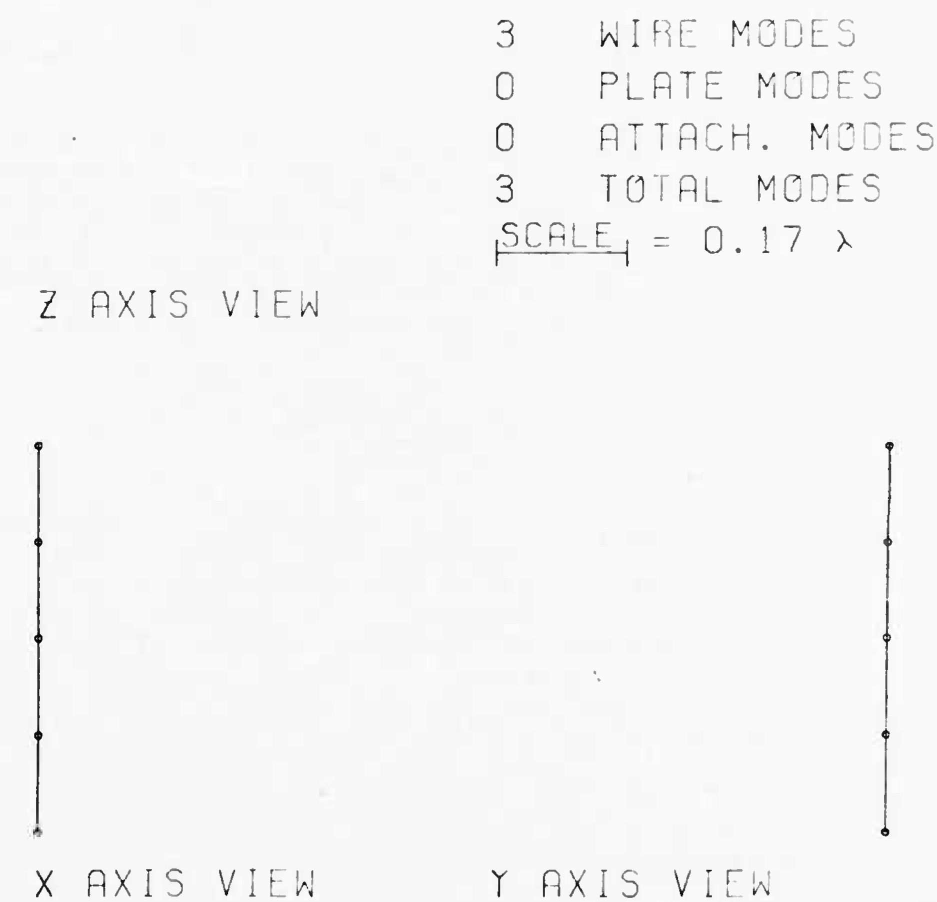


Figure 13 - A three view plot of the geometry of Example 2.

3.3 EXAMPLE 2

Here we wish to find the input impedance of a center fed half-wave dipole of radius 0.001 wavelength, and assuming perfect conductivity of the wire. The subroutine WGEOM, shown in Figure 5 sets up a center fed dipole of length 0.5 meters and with 4 segments. It will be a half-wave dipole if the frequency = 300 MHZ. Figure 12 shows the required input file for this problem. Note that in READ 1, IWRZT = 1 which will result in a printout of the moment method impedance matrix. Also, in READ 1 IRGM = 0, so that the wire geometry is to be generated in subroutine WGEOM (rather that from READ's 11-15 of the input file). A three view orthographic plot of the dipole is shown in Figure 13.

The output is shown in Appendix II. The only portion of the output not previously described is the printing of the impedance matrix. This occurs just above the printout of the input admittance. The lower triangular part of the symmetric impedance matrix is printed by columns. Following this, the input impedance of the half-wave dipole is shown as about 81 +j41 ohms. Note that this run took about 0.5 seconds.

3.4 EXAMPLE 3

In this example, we will illustrate a scattering computation involving intersecting plates. Say, for example, that we wish to compute the backscatter from the corner reflector shown in Figure 14. It consists of two 1.0 by 0.5 wavelength plates, intersecting along the z axis. The input for this geometry is shown in Figure 15. A backscatter azimuth pattern in the plane theta = 90.0 degrees is specified by setting ISA = 1 and THSA = 90.0 in READ 5. In READ 7 IOVL = 2 so that overlap modes will be inserted to connect the two plates. Figure 16 show the orthagraphic view and Appendix III shows the output. Note that after specifying the coordinates of plates 1 and 2, the output indicates that 4 overlap modes were inserted connecting side 1 of plate 1 to side 1 of plate 2. See Figure 2 for definition of plate sides. The backscatter patterns for theta (STTM) and phi (SPPM) polarization are shown, and plotted in Figures 17a,b. The cross polarization is not plotted since it is so small.

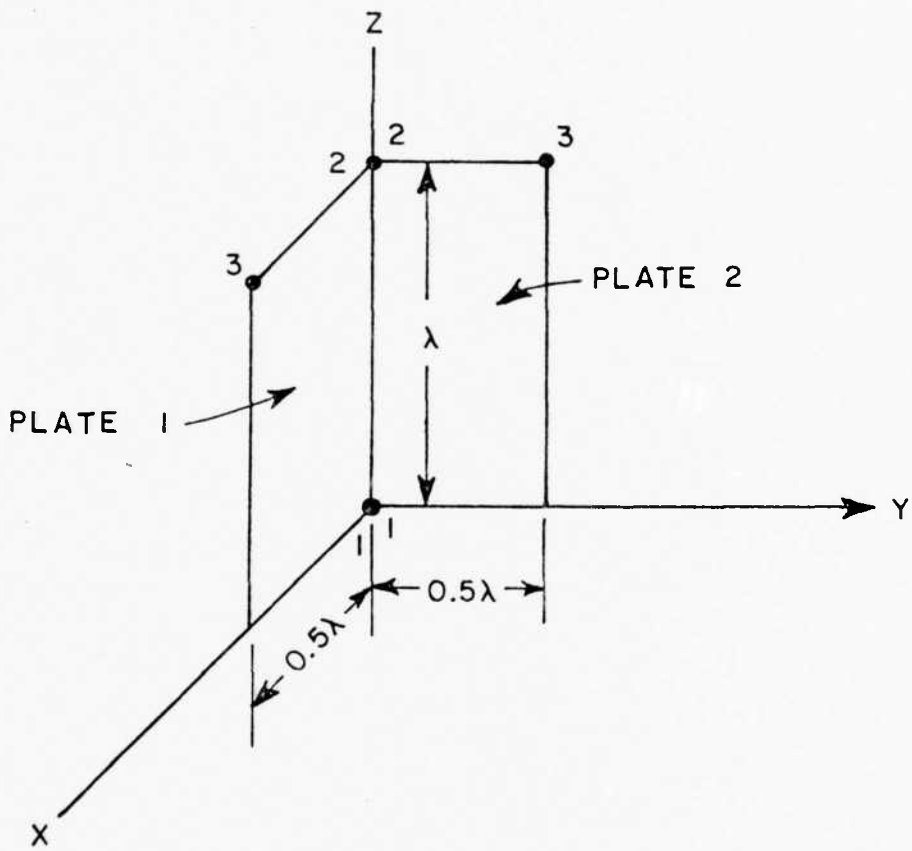


Figure 14 - Geometry for the corner reflector of Example 3

```
1 2 1 1 0 0 4 10 18 0 1
0 1 3 0.0
0 1 3 90.0
0 1 3 0.0 90.0 0.0
1 1 5 90.0
300.0 -1.0 0.001
2 2
4 2 3
0.0 0.0 0.0
0.0 0.0 1.0
0.5 0.0 1.0
4 2 3
0.0 0.0 0.0
0.0 0.0 1.0
0.0 0.5 1.0
0 0
```

Figure 15 - Input file for Example 3.

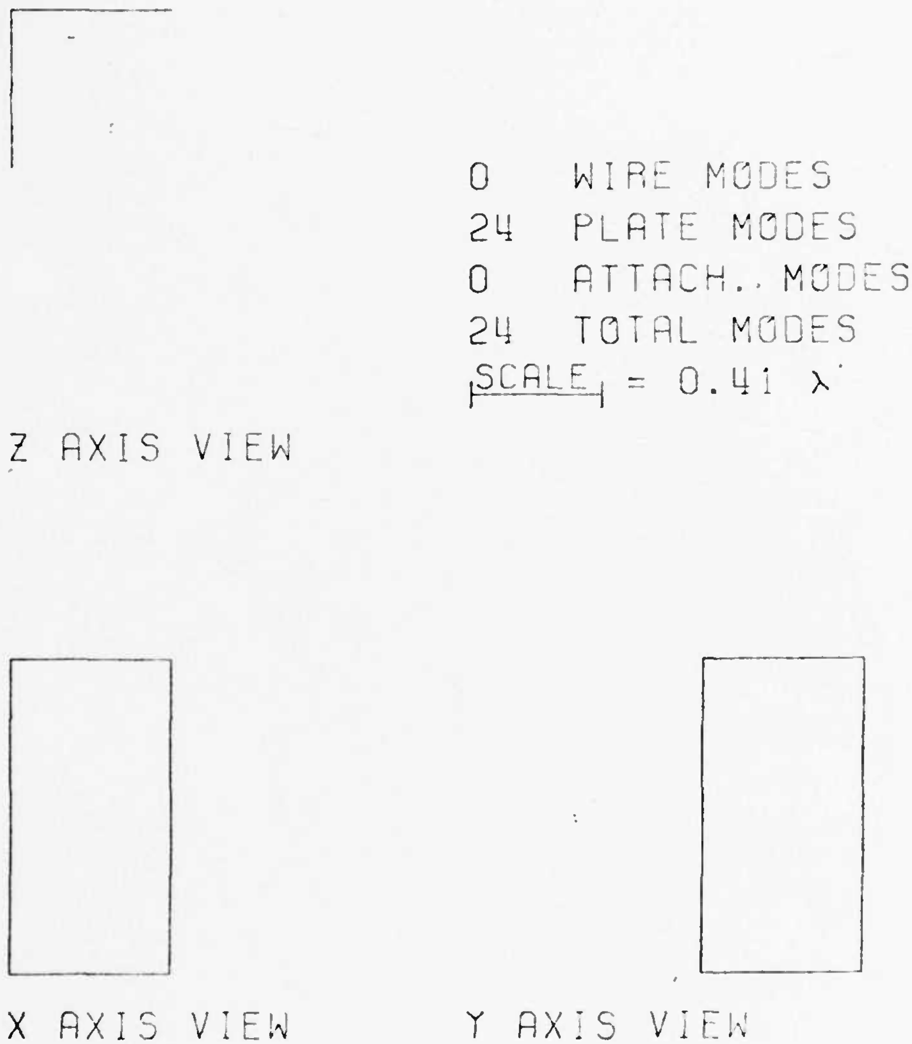


Figure 16 - A three view plot of the geometry of Example 3.

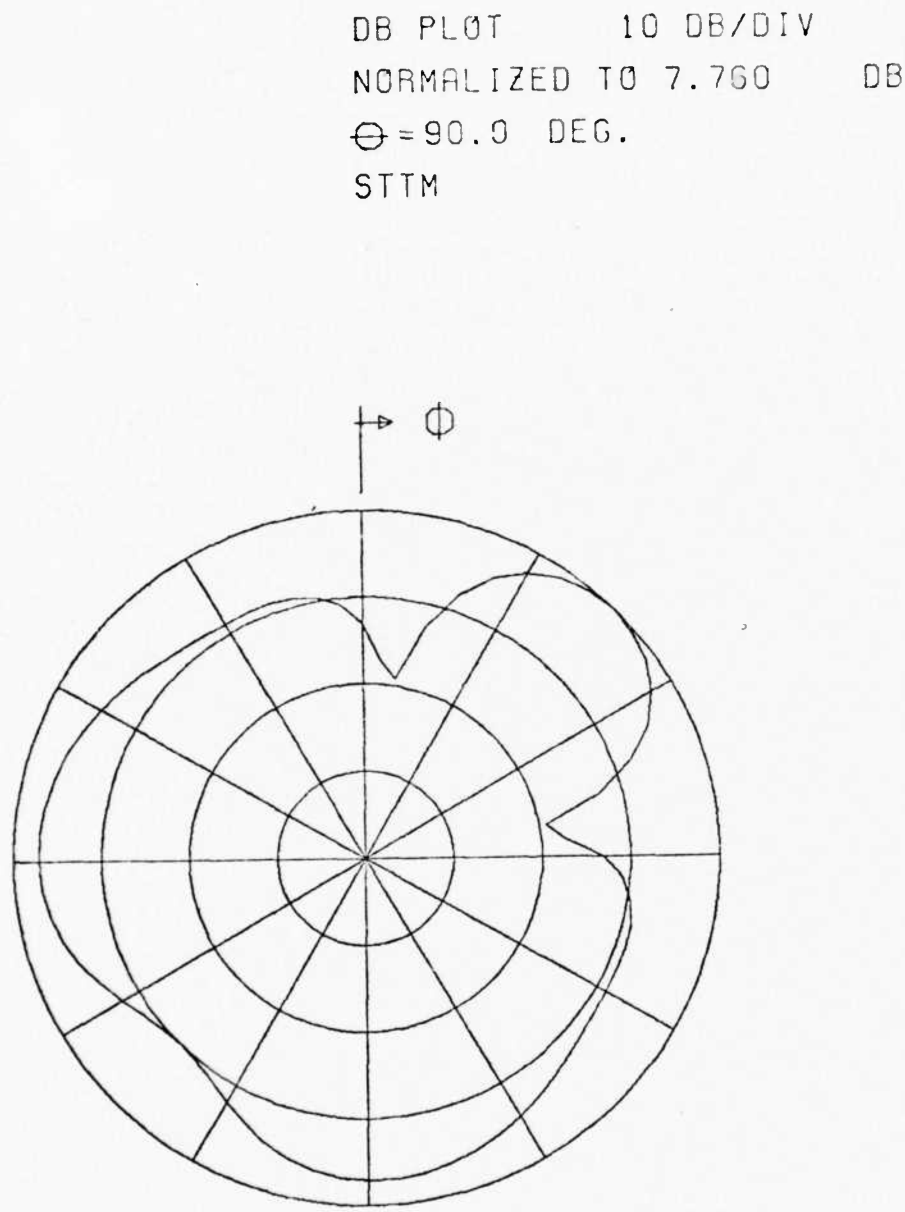


Figure 17a - Theta polarized azimuth backscatter pattern for Example 3.

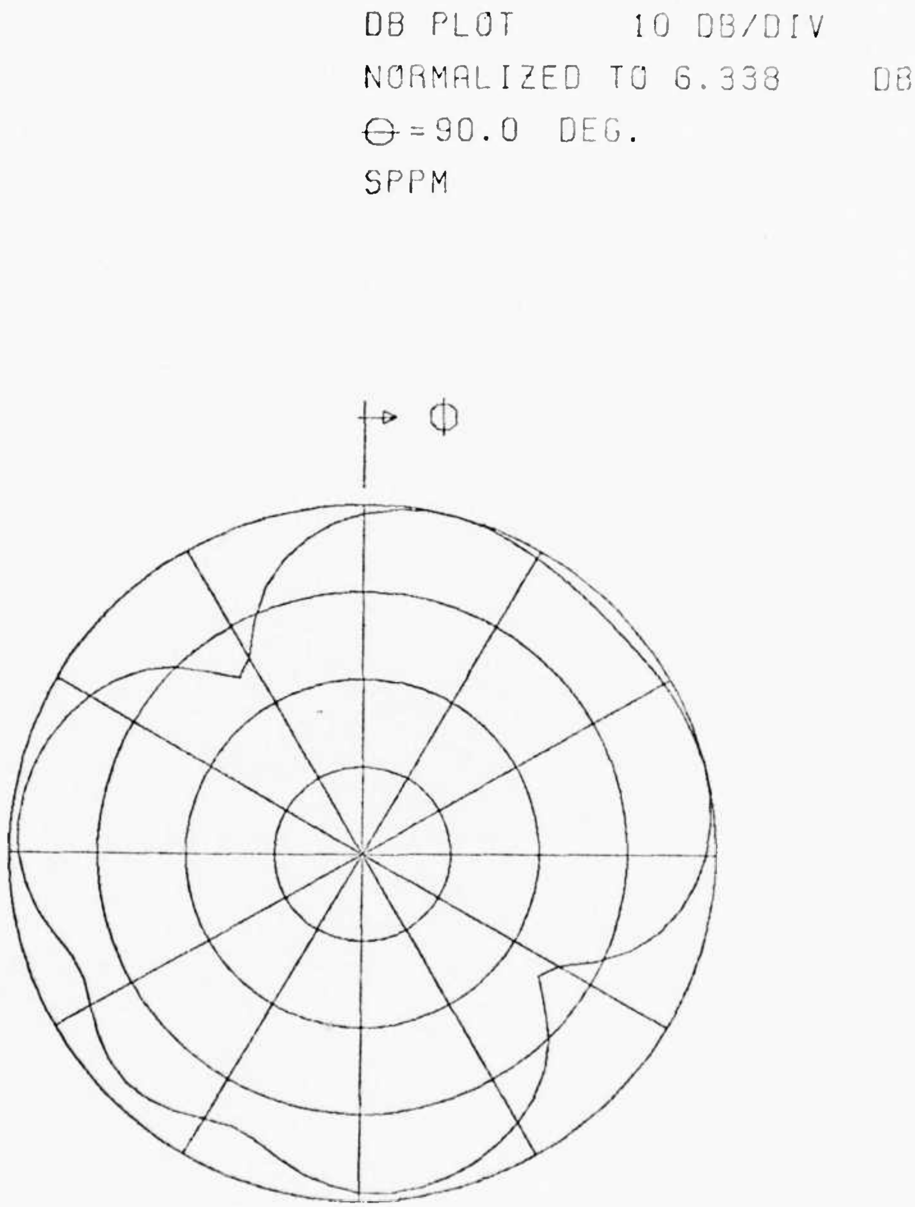


Figure 17b - Phi polarized azimuth backscatter pattern for Example 3.

3.5 EXAMPLE 4

Example 4 is identical to Example 3 except that we wish a bistatic scattering pattern, with the incident wave comming from theta = 90.0 degrees and phi = 45.0 degrees. Thus, we now set THIN = 90.0 and PHIN = 45.0 in READ 4, and ISA = 2 in READ 5. The input file is shown in Figure 18, and Appendix IV shows the output. The bistatic scattering patterns are shown in Figures 19a,b.

3.6 EXAMPLE 5

This example will illustrate the use of READ 10 to save computational time. Say we are given the problem of computing the input impedance of a quarter wave monopole at several locations on plate 2 of the three plate bend illustrated in Figure 20a. Here we will compute the input impedance for the monopole attached at location 1 = (x,y,z) = (0.0,0.0,0.0) and at location 2 = (x,y,z) = (0.0,0.3,0.0). Computation time will be saved by noting that when the monopole moves from location 1 to location 2, the plate geometry does not change. Thus all of the plate to plate impedances do not change.

To find the impedance at these two locations we will set NWG = 2 in READ 1, indicating that we are running two wire geometries. For the first geometry we will set IWRZM = 1 and IRDZM = 0 in READ 10. Thus for the first geometry we will compute the entire impedance matrix and then write it, unformatted, onto the disk file ZMAT.DAT.1 (logical unit 1). For the second geometry we will set IRDZM = 2, indicating that the impedance matrix is to be read in, unformatted, from file ZMAT.DAT.1 on logical unit 1. Also the plate to plate block of the impedance matrix is not be recomputed, resulting in a savings of time. For the second geometry IWRZT may be set to 0 or 1. Figure 21 shows the input file. READ 10 is at lines 2000 and 2800. The monopole is composed of two segments as seen in Figure 20b. The wire is perfectly conducting with radius of 0.001 meters. Figure 22 shows the three view orthographic plot with the monopole at location 1. the output file is shown in Appendix V. Note that for the first geometry where the entire impedance matrix was computed (IRDZM = 0)the run time was about 411 seconds. However, for the second geometry, where where the impedance matrix was read in and the plate to plate block was not computed (IRDZM = 2), the time was reduced to 98 seconds.

```
1 2 1 1 0 0 4 10 18 0 1
0 1 3 0.0
0 1 3 90.0
0 1 3 0.0 90.0 45.0
2 1 5 90.0
300.0 -1.0 0.001
2 2
4 2 3
0.0 0.0 0.0
0.0 0.0 1.0
0.5 0.0 1.0
4 2 3
0.0 0.0 0.0
0.0 0.0 1.0
0.0 0.5 1.0
0 0
```

Figure 18 - Input file for Example 4.

DB PLOT 10 DB/DIV

NORMALIZED TO 7.894 DB

Θ = 90.0 DEG.

STTM

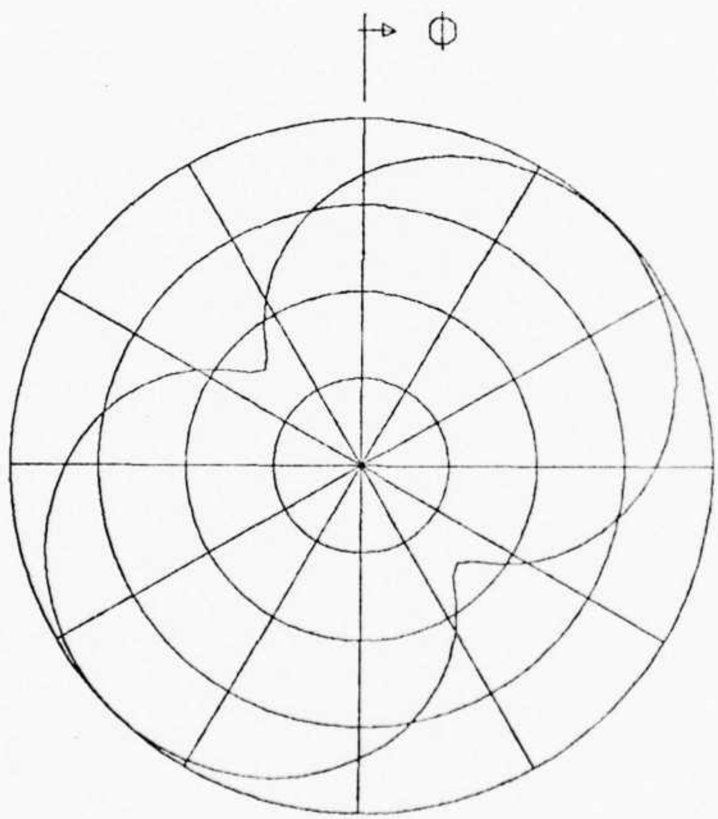


Figure 19a - Theta polarized azimuth bistatic scattering pattern for Example 4.

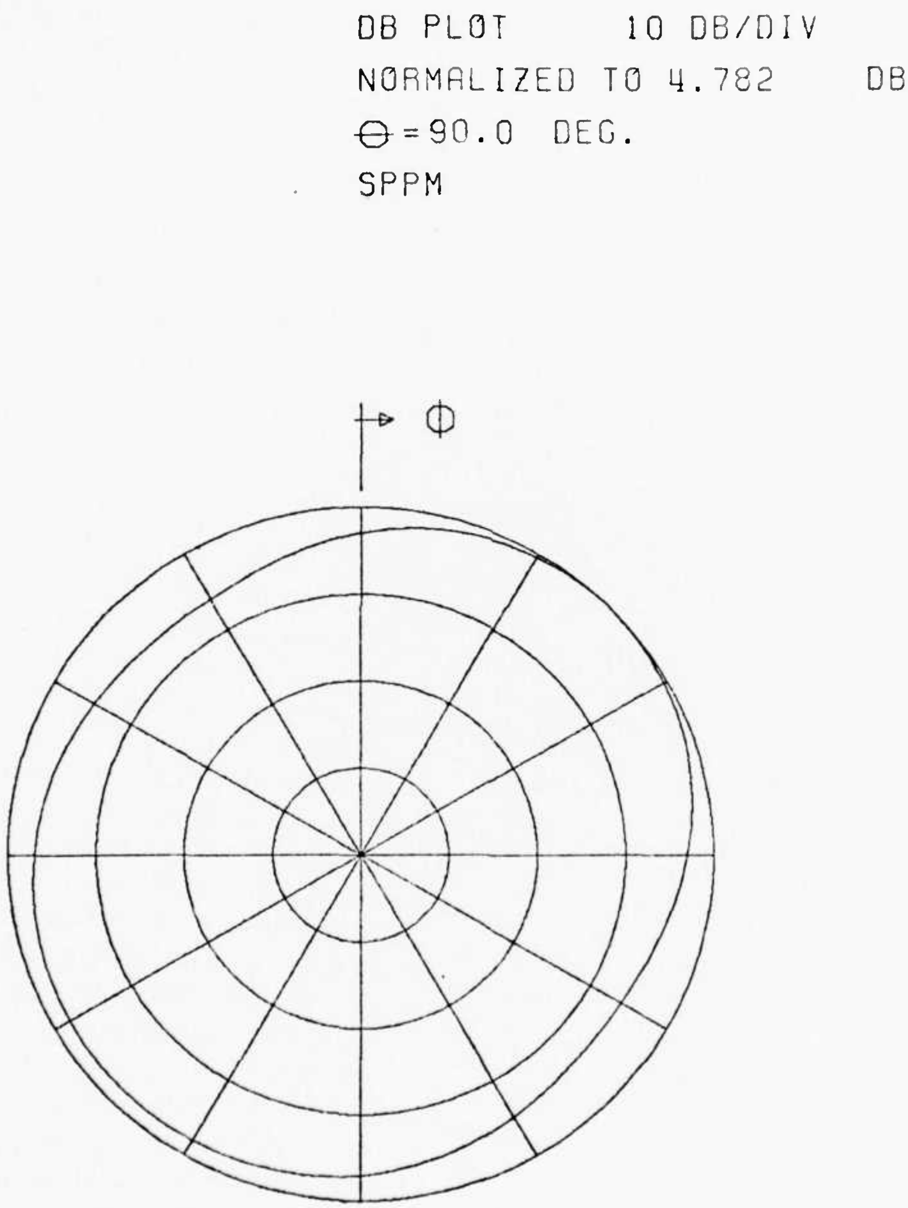
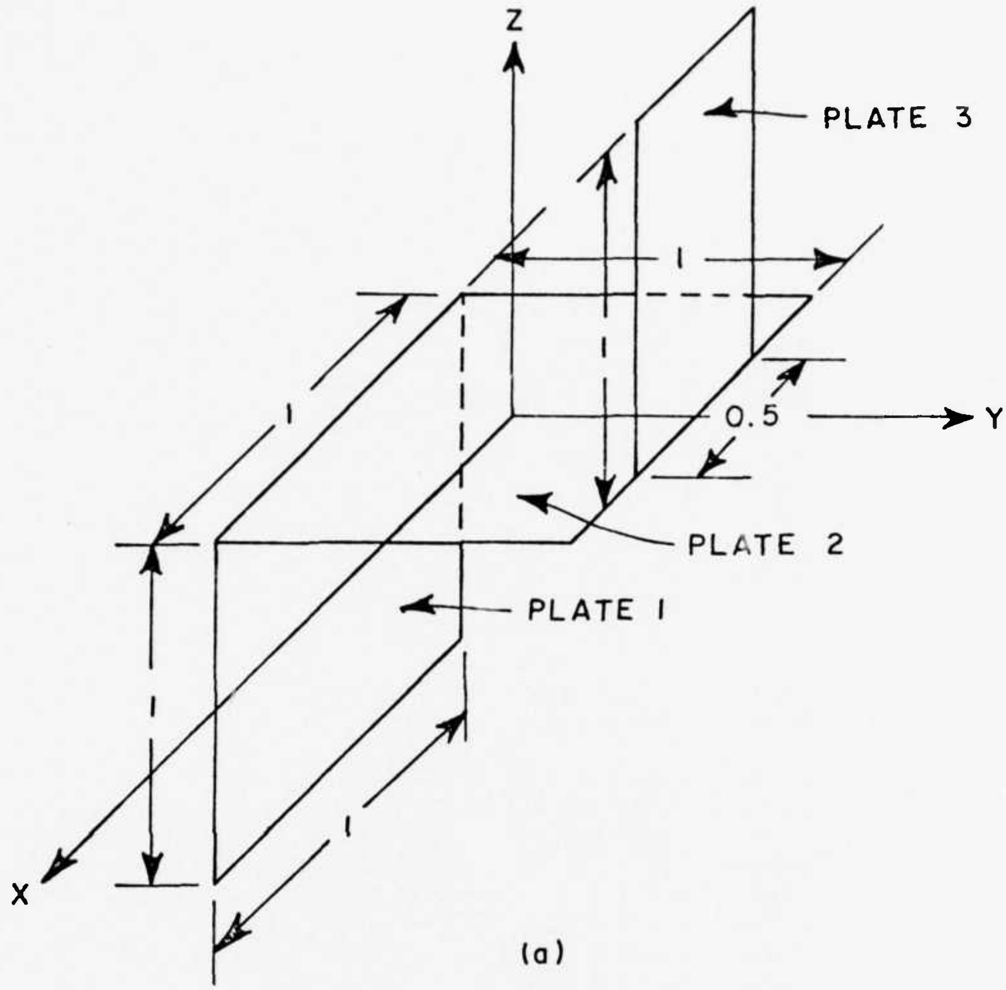


Figure 19b - Phi polarized azimuth bistatic scattering pattern for Example 4.



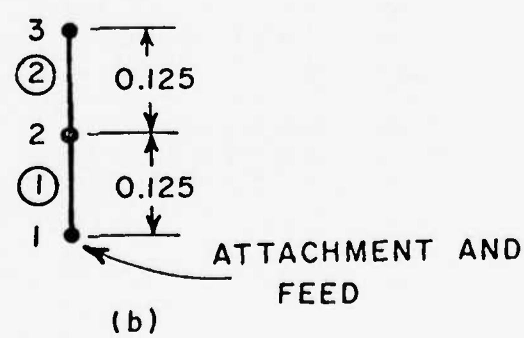


Figure 20a - Geometry for the three plate bend of Example 5.(b) Geometry for wire of Example 5

```
1 2 1 2 0 0 4 10 18 1 1
0 0 3 0.0
0 1 3 90.0
0 1 3 0.0 90.0 0.0
0 1 3 90.0
300.0 -1.0 0.001
3 2
4 4 3
0.5 -0.5 -1.0
0.5 -0.5 0.0
-0.5 -0.5 0.0
4 4 3
0.5 -0.5 0.0
0.5 0.5 0.0
-0.5 0.5 0.0
2 4 3
0.25 0.5 0.0
-0.25 0.5 0.0
-0.25 0.5 1.0
1 0
2 3 1 0
0.0 0.0 0.0
0.0 0.0 0.125
0.0 0.0 0.25
1 2
2 3
1 0 2 (1.0,0.0) (0.0,0.0) 0.2
0 2
2 3 1 0
0.0 0.3 0.0
0.0 0.3 0.125
0.0 0.3 0.25
1 2
2 3
1 0 2 (1.0,0.0) (0.0,0.0) 0.2
```

Figure 21 - Input file for Example 5.

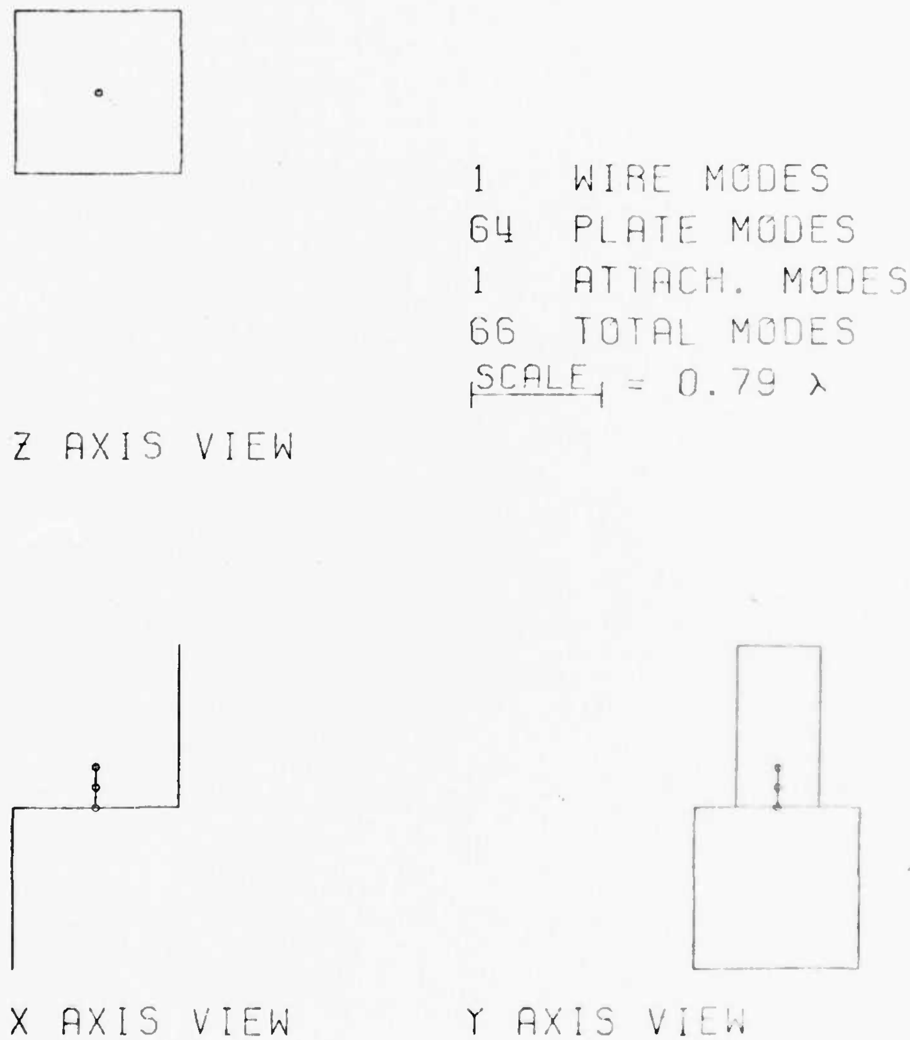


Figure 22 - A three view plot of the geometry of Example 5.

CHAPTER 4

ARRAY DIMENSIONS AND FILE DESCRIPTIONS

4.1 ARRAY DIMENSIONS

The array dimensions are defined by DIMENSION and COMPLEX statements located near the top of the main program. All arrays have either fixed dimensions, independent of the geometry being run, or are dimensioned according to one of the following dimension indicators:

INM = maximum number of wire segments.
ICJ = maximum number of wire modes.
IDC = maximum number of elements in wire/wire block of impedance matrix.
IPLM = maximum number of plate modes.
IPL = maximum number of plates.
IAT = maximum number number of wire to plate attachments.
INP = maximum number of wire points.
ITOT = maximum total number of modes (wire + plate + attach.).
IDZT = maximum number of elements in impedance matrix.

The dimension indicators are defined below the DIMENSION and COMPLEX statements, and typically have the values:

INM = 491
ICJ = 492
IDC = (ICJ*ICJ+ICJ)/2
IPLM = 490
IPL = 7
IAT = 2
INP = 493
ITOT = 495
IDZT = (ITOT*ITOT+ITOT)/2

Thus the program is typically set for no more than INM = 491 wire segments, ICJ = 492 wire modes, IDC = 121,278 elements in the (lower triangular part of the) wire to wire block of the impedance matrix, IPLM = 490 plate modes, IPL = 7

plates, IAT = 2 attachment points or modes, INP = 493 wire points, ITOT = 495 total modes, and IDZT = 122,760 elements in the (lower triangular part of the symmetric) impedance matrix. Note that while the number wire modes can be up to 492, the number of plate modes up to 490, or the number of attachment modes up to 2, the total number of modes can not exceed 495.

There are two steps required to change the allowed dimensions:

1. One must change the appropiate dimension indicator.

2. One must re-dimension all arrays associated with that dimension indicator. Arrays dimensioned by the same indicator are grouped together, and are clearly marked by COMMENT statements.

4.2 FILE DESCRIPTIONS

A description of program or source files and I/O files will now be given.

4.2.1 PROGRAM FILES

The computer code is contained in several different (disk) files on the ElectroScience Lab's Digital Equipment Corporation VAX computer system. A listing of these files follows. The file types are shown as FORTRAN (except for 'PLOTLIB which an object file).

STDMM.FOR - the main program plus various surface patch subroutines
THNWRS.FOR - various thin wire subroutines
WGEOM.FOR - subroutine, written by the user, describing the WIRE geometry (see section 2.3)
LIB.FOR - various special library routines. At present we use only the function subroutine GETCP(I) where I = clock reading in hundreths of a second. Since this routine tends to be hardware dependent, it is not included when the program is sent outside the ESL.
GPLOT.FOR - subroutine to a make three view orthographic plot of wire and plate geometry
'PLOTLIB - contains various plotting subroutines. If the code is being sent outside the ESL some routines must be omitted due to contactural restrictions. When this file is supplied to an

outside user it will be termed PLOTLIB.FOR. Of the many subroutines omitted,the only four used in the code are:

VPLOTS(I,0,0)
VPLOTS reserves the plotter.

I = 1 implies the plot is for the Versatek paper plotter
    2 implies the plot is for the Megatek CRT plotter
    0 implies the program gives the user a choice of plotter

PLOT(X,Y,I)
PLOT moves the the pen, with pen up or down.

X,Y implies move pen to these coordinates (inches)
I = 2 implies lower pen before moving
  = 3 implies raise pen before moving
  = -2 or -3 implies same as 2 or 3 except reset origon after moving
  = -999 implies go to lower left corner of next page with pen up and reset origon
  = 999 implies this is the last plotting call so plot everything in the plot buffer and release the plotter

A call to VPLOTS must precede all plotting, and call to PLOT with I = 999 must be the last plotting call.

NUMBER(X,Y,HT,FPN,ANGLE,N)
NUMBER plots out a floating point number.

X,Y = coordinates of lower corner of output number in inches
HT = height of the output number in inches. If HT > 0, then the output will be plotted to the right of X,Y; if HT < 0, it will be plotted to the left.
FPN = floating point number to be plotted
ANGLE = angle in degrees (counterclockwise) with respect to the X axis at which the output number is to be plotted
N = an integer specifying the output format. If ABS(N) < 100, then FPN will be plotted in the "F" format. If N > 0, then N digits will be plotted after the decimal point in addition to all digits before the decimal point. If N < 0, then no digits will be plotted after the decimal point, and the decimal point plus the first -N-1 digits to the left of the decimal point will be suppressed. If ABS(N) >= 100, then FPN will be plotted in an E format, that is, the mantissa of FPN followed by an "X", followed by a 10 raised to a power. If N > 100, then there will be one digit to the left and N-100 digits to the right of the decimal point in the mantissa. If N < -100, then an integer mantissa of -N-100 digits followed by a power of 10 will be plotted.

SYMBOL(X,Y,HT,LABEL,ANGLE,NC)
SYMBOL plots a character or string of characters.

ARRAY DIMENSIONS AND FILE DESCRIPTIONS

X,Y = coordinates in inches of the lower left hand corner of the symbol to be drawn
HT = the height in inches of the character to be drawn. HT should be a multiple of 7 times the plotter increment.
LABEL = if NC > 0, then LABEL is a literal variable or constant representing the character string to be plotted. NC = the number of characters to be plotted.
= if NC = -1, then LABEL is an integer expression ranging from 0 to 127 which represents a single character to be plotted. These symbols and their codes are given in Figure 23.
ANGLE = angle in degrees between the symbol to be plotted and the X axis
NC = see LABEL

If the user can not supply a subroutine GETCP, then all references to this subroutine must be deleted, and the program will not supply run time information. If subroutines NUMBER SYMBOL VPLOTS and PLOT are not available, then all calls to plotting subroutines must be eliminated. It is felt in most cases, if a plotter is available, then these routines will also be available. If plotting is not desired then subroutines POLAR and GPLOT should be removed. All calls to these and to subroutines PLOT, VLOTS, and SYMBOL should be removed or COMMENTED out.

In summary when the code is supplied outside the ESL the following FORTRAN files are included in a single file called OSUESP.FOR:

STDMM.FOR
THNWRS.FOR
WGEOM.FOR (see Figure 5)
GPLOT.FOR
PLOTLIB.FOR

Note that the subroutine WGEOM supplied is for a dipole. To obtain a new geometry, then he must write a new subroutine WGEOM and replace the one supplied (see Chapter 2 on READ 1 and SUBROUTINE WGEOM). Unless otherwise indicated the magnetic tape format is:

ANSI ASCII label - OSUESP
9 track 800 bits/inch
Not blocked (80 characters/record)
ASCII character set

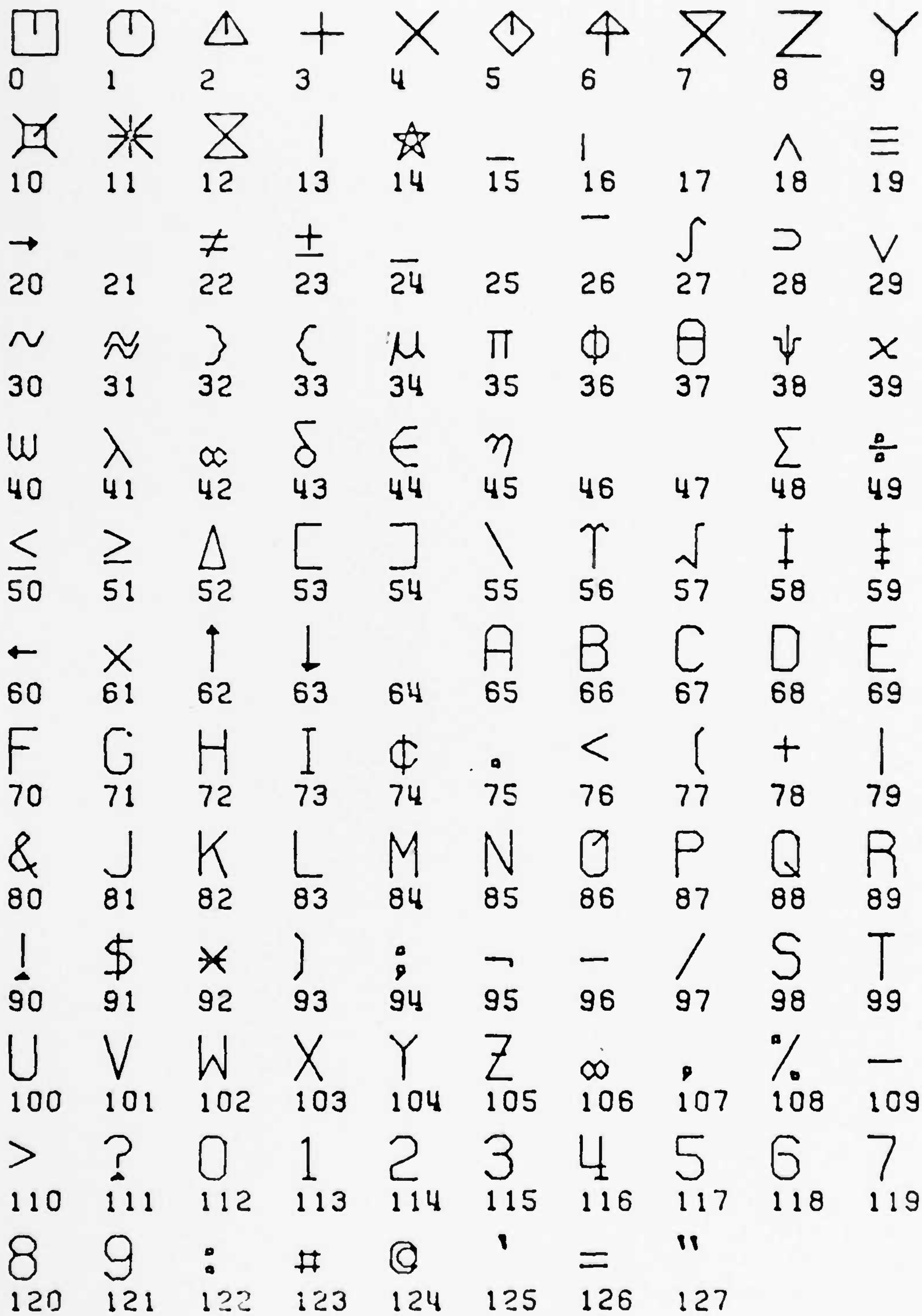


Figure 23 - Symbol table.

4.2.2 INPUT/OUTPUT FILES

The following files are used to input and output data.

INSTD.DAT - the input file described in Chapter 2. It must be defined as logical unit 5 by the user.

OUTFL.DAT - the output file as described in Chapter 3 and shown in the appendices. It is defined as logical unit 6 via OPEN and CLOSE statement in the main program.

ZMAT.DAT - input and output of the impedance matrix as described in section 2.2.5. It is defined as logical unit 1 via OPEN and CLOSE statements in the main program.

APPENDIX A

OUTPUT FOR DESIGN EXAMPLE 1

INPUT DATA

FREQ.(MHZ) = 150.000 WAVE(M) = 2.000 WIRE RADIUS(M) = 0.0010000
INTP= 10 INTD= 18 INT = 4

WIRE CONDUCTIVITY = 38.00 MEGAMHOS/M

GEOMETRY FOR THE 1 PLATES

PLATE NUMBER 1

NM12 = 4 NM23 = 4 IP = 3
X,Y,Z COOR.(METERS) OF CORNER 1 = -0.500 -0.500 0.000
X,Y,Z COOR.(METERS) OF CORNER 2 = 0.500 -0.500 0.000
X,Y,Z COOR.(METERS) OF CORNER 3 = 0.500 0.500 0.000

COOR.(METERS) OF 24 MODES ON THIS PLATE

I	XA1	YA1	ZA1	XA2	YA2	ZA2	XA3	YA3	ZA3	XB1	YB1	ZB1	XB2	YB2	ZB2	XB3	YB3	ZB3
1	-0.25	-0.50	0.00	-0.50	-0.50	0.00	-0.50	-0.25	0.00	-0.25	-0.50	0.00	0.00	-0.50	0.00	0.00	-0.25	0.00
2	0.00	-0.50	0.00	-0.25	-0.50	0.00	-0.25	-0.25	0.00	0.00	-0.50	0.00	0.25	-0.50	0.00	0.25	-0.25	0.00
3	0.25	-0.50	0.00	0.00	-0.50	0.00	0.00	-0.25	0.00	0.25	-0.50	0.00	0.50	-0.50	0.00	0.50	-0.25	0.00
4	-0.25	-0.25	0.00	-0.50	-0.25	0.00	-0.50	0.00	0.00	-0.25	-0.25	0.00	0.00	-0.25	0.00	0.00	0.00	0.00
5	0.00	-0.25	0.00	-0.25	-0.25	0.00	-0.25	0.00	0.00	0.00	-0.25	0.00	0.25	-0.25	0.00	0.25	0.00	0.00
6	0.25	-0.25	0.00	0.00	-0.25	0.00	0.00	0.00	0.00	0.25	-0.25	0.00	0.50	-0.25	0.00	0.50	0.00	0.00
7	-0.25	0.00	0.00	-0.50	0.00	0.00	-0.50	0.25	0.00	-0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00
8	0.00	0.00	0.00	-0.25	0.00	0.00	-0.25	0.25	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.25	0.25	0.00
9	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.25	0.00	0.00	0.50	0.00	0.00	0.50	0.25	0.00
10	-0.25	0.25	0.00	-0.50	0.25	0.00	-0.50	0.50	0.00	-0.25	0.25	0.00	0.00	0.25	0.00	0.00	0.50	0.00
11	0.00	0.25	0.00	-0.25	0.25	0.00	-0.25	0.50	0.00	0.00	0.25	0.00	0.25	0.25	0.00	0.25	0.50	0.00
12	0.25	0.25	0.00	0.00	0.25	0.00	0.00	0.50	0.00	0.25	0.25	0.00	0.50	0.25	0.00	0.50	0.50	0.00
13	-0.50	-0.25	0.00	-0.50	-0.50	0.00	-0.25	-0.50	0.00	-0.50	-0.25	0.00	-0.50	0.00	0.00	-0.25	0.00	0.00

14	-0.50	0.00	0.00	-0.50	-0.25	0.00	-0.25	-0.25	0.00	-0.50	0.00	0.00	-0.50	0.25	0.00	-0.25	0.25	0.00
15	-0.50	0.25	0.00	-0.50	0.00	0.00	-0.25	0.00	0.00	-0.50	0.25	0.00	-0.50	0.50	0.00	-0.25	0.50	0.00
16	-0.25	-0.25	0.00	-0.25	-0.50	0.00	0.00	-0.50	0.00	-0.25	-0.25	0.00	-0.25	0.00	0.00	0.00	0.00	0.00
17	-0.25	0.00	0.00	-0.25	-0.25	0.00	0.00	-0.25	0.00	-0.25	0.00	0.00	-0.25	0.25	0.00	0.00	0.25	0.00
18	-0.25	0.25	0.00	-0.25	0.00	0.00	0.00	0.00	0.00	-0.25	0.25	0.00	-0.25	0.50	0.00	0.00	0.50	0.00
19	0.00	-0.25	0.00	0.00	-0.50	0.00	0.25	-0.50	0.00	0.00	-0.25	0.00	0.00	0.00	0.00	0.25	0.00	0.00
20	0.00	0.00	0.00	0.00	-0.25	0.00	0.25	-0.25	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.25	0.25	0.00
21	0.00	0.25	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.25	0.00	0.00	0.50	0.00	0.25	0.50	0.00
22	0.25	-0.25	0.00	0.25	-0.50	0.00	0.50	-0.50	0.00	0.25	-0.25	0.00	0.25	0.00	0.00	0.50	0.00	0.00
23	0.25	0.00	0.00	0.25	-0.25	0.00	0.50	-0.25	0.00	0.25	0.00	0.00	0.25	0.25	0.00	0.50	0.25	0.00
24	0.25	0.25	0.00	0.25	0.00	0.00	0.50	0.00	0.00	0.25	0.25	0.00	0.25	0.50	0.00	0.50	0.50	0.00

4 POINTS ON THE WIRE

I	X (I)	Y (I)	Z (I)
1	0.0000E+00	0.0000E+00	0.0000E+00
2	0.0000E+00	0.0000E+00	0.2500E+00
3	0.0000E+00	0.0000E+00	0.5000E+00
4	-0.3000E+00	0.0000E+00	0.2500E+00

MODES ON THE WIRE STRUCTURE

MAXIMUM NUMBER OF MODES AT ONE POINT = 2
MINIMUM NUMBER OF MODES AT ONE POINT = 1
NUMBER OF WIRE MODES = 2

I	I1(I)	I2(I)	I3(I)	JA(I)	JB(I)
1	1	2	3	1	2
2	3	2	4	2	3

3 SEGMENTS ON THE WIRE

J	IA(J)	IB(J)	D(J)(M)
1	1	2	0.25000E+00
2	2	3	0.25000E+00
3	2	4	0.30000E+00

GEOMETRY FOR THE 1 ATTACHMENT POINTS

I SEGMENT END PLATE H(M)

```
1     1     0     1     0.40000

  LISTING OF LOADS AND GENERATORS

   0.5000E+02   0.0000E+00 OHMS BY PT. A OF SEGMENT   3
   0.1000E+01   0.0000E+00 VOLTS AT ATTACHMENT  1

  NWP = NUMBER OF WIRE MODES =    2
  NPLTM = NUMBER OF PLATE MODES =   24
  NAT = NUMBER OF ATTACHMENT MODES =    1
```

ANTENNA MODAL CURRENTS

0

MODE	REL MAG	ABS MAG	PHASE	*** COMPLEX ***	
1	1.000	0.0080185	-76.	0.001928	-0.007783
2	0.546	0.0043757	-81.	0.000716	-0.004317
3	0.079	0.0006349	-86.	0.000039	-0.000634
4	0.025	0.0002006	-111.	-0.000072	-0.000187
5	0.044	0.0003503	116.	-0.000152	0.000316
6	0.133	0.0010643	-82.	0.000154	-0.001053
7	0.053	0.0004285	-89.	0.000010	-0.000428
8	0.073	0.0005878	108.	-0.000179	0.000560
9	0.133	0.0010643	-02.	0.000154	-0.001053
10	0.053	0.0004285	-89.	0.000010	-0.000428
11	0.073	0.0005R78	10R.	-0.000179	0.000560
12	0.079	0.0006349	-86.	0.000039	-0.000634
13	0.025	0.0002006	-111.	-0.000072	-0.000187
14	0.044	0.0003503	116.	-0.000152	0.000316
15	0.064	0.0005120	-80.	0.000095	-0.000505
16	0.000	0.0000000	0.	0.000000	0.000000
17	0.064	0.0005120	100.	-0.000086	0.000505
18	0.091	0.0007270	-78.	0.000150	-0.000711
19	0.000	0.0000000	168.	0.000000	0.000000
20	0.091	0.0007270	102.	-0.000150	0.000711
21	0.085	0.0006837	-78.	0.000142	-0.000669
22	0.000	0.0000000	34.	0.000000	0.000000
23	0.085	0.0006837	102.	-0.000142	0.000669
24	0.061	0.0004915	-80.	0.000085	-0.000484
25	0.000	0.0000000	-32.	0.000000	0.000000
26	0.061	0.0004915	100.	-0.000085	0.000484
27	0.962	0.0077102	-71.	0.002451	-0.007310

0

```
INPUT ADMITTANCE(MHOS) =   0.002451 J  -0.007310
INPUT IMPEDANCE(OHMS) =     41.225 J    122.272
EFFICIENCY(PERCENT) =  60.407
```

ANTENNA PROBLEM, ISCAT = 0

ELEVATION PATTERN, PHI = 0.0 DEG.

THETA(DEG)	GTHETA(DB)	GPHI(DB)
0	-11.470	-99.900
3	-10.404	-99.900
6	-9.177	-99.900
9	-8.065	-99.900
12	-7.077	-99.900
15	-6.201	-99.900
18	-5.431	-99.900
21	-4.753	-99.900
24	-4.159	-99.900
27	-3.638	-99.900
30	-3.184	-99.900
33	-2.790	-99.900
36	-2.449	-99.900
39	-2.155	-99.900
42	-1.905	-99.900
45	-1.693	-99.900
48	-1.517	-99.900
51	-1.371	-99.900
54	-1.254	-99.900
57	-1.161	-99.900
60	-1.090	-99.900
63	-1.038	-99.900
66	-1.001	-99.900
69	-0.979	-99.900
72	-0.968	-99.900
75	-0.967	-99.900
78	-0.975	-99.900
81	-0.990	-99.900
84	-1.015	-99.900
87	-1.067	-99.900
90	-1.025	-99.900
93	-0.995	-99.900
96	-1.057	-99.900
99	-1.108	-99.900
102	-1.158	-99.900
105	-1.215	-99.900
108	-1.284	-99.900
111	-1.365	-99.900
114	-1.461	-99.900
117	-1.575	-99.900
120	-1.712	-99.900
123	-1.874	-99.900
126	-2.065	-99.900
129	-2.290	-99.900
132	-2.552	-99.900
135	-2.855	-99.900
138	-3.208	-99.900

141	-3.615	-99.900
144	-4.083	-99.900
147	-4.622	-99.900
150	-5.243	-99.900
153	-5.959	-99.900
156	-6.785	-99.900
159	-7.747	-99.900
162	-8.872	-99.900
165	-10.199	-99.900
168	-11.777	-99.900
171	-13.661	-99.900
174	-15.957	-99.900
177	-19.211	-99.900
180	-18.094	-99.900
183	-16.958	-99.900
186	-15.175	-99.900
189	-13.173	-99.900
192	-11.400	-99.900
195	-9.873	-99.900
198	-8.615	-99.900
201	-7.525	-99.900
204	-6.592	-99.900
207	-5.785	-99.900
210	-5.086	-99.900
213	-4.479	-99.900
216	-3.950	-99.900
219	-3.470	-99.900
222	-3.090	-99.900
225	-2.742	-99.900
228	-2.441	-99.900
231	-2.181	-99.900
234	-1.957	-99.900
237	-1.768	-99.900
240	-1.607	-99.900
243	-1.472	-99.900
246	-1.359	-99.900
249	-1.267	-99.900
252	-1.192	-99.900
255	-1.135	-99.900
258	-1.093	-99.900
261	-1.066	-99.900
264	-1.055	-99.900
267	-1.074	-99.900
270	-1.025	-99.900
273	-0.995	-99.900
276	-1.052	-99.900
279	-1.105	-99.900
282	-1.170	-99.900
285	-1.250	-99.900
288	-1.347	-99.900
291	-1.459	-99.900
294	-1.612	-99.900
297	-1.783	-99.900
300	-1.993	-99.900
303	-2.217	-99.900

306	-2.489	-99.900
309	-2.802	-99.900
312	-3.163	-99.900
315	-3.576	-99.900
318	-4.049	-99.900
321	-4.587	-99.900
324	-5.201	-99.900
327	-5.899	-99.900
330	-6.691	-99.900
333	-7.589	-99.900
336	-8.601	-99.900
339	-9.727	-99.900
342	-10.942	-99.900
345	-12.166	-99.900
348	-13.208	-99.900
351	-13.763	-99.900
354	-13.583	-99.900
357	-12.721	-99.900
360	-11.470	-99.900

CPU RUN TIME FOR RUN 1 GEOMETRY 1 = 117.26 SECONDS

TOTAL CPU RUN TIME = 117.43 SECONDS

APPENDIX B

OUTPUT FOR DESIGN EXAMPLE 2

```
INPUT DATA

FREQ.(MHZ) =    300.000   WAVE(M) =      1.000   WIRE RADIUS(M) =  0.0010000
INTP=  10   INTD=  18   INT =    4

WIRE CONDUCTIVITY = -1.00 MEGAMHOS/M


GEOMETRY FOR THE    0 PLATES



  5 POINTS ON THE WIRE
 I          X (I)          Y (I)          Z (I)

 1    0.0000E+00     0.0000E+00     0.0000E+00
 2    0.0000E+00     0.0000E+00     0.1250E+00
 3    0.0000E+00     0.0000E+00     0.2500E+00
 4    0.0000E+00     0.0000E+00     0.3750E+00
 5    0.0000E+00     0.0000E+00     0.5000E+00


MODES ON THE WIRE STRUCTURE

MAXIMUM NUMBER OF MODES AT ONE POINT =  2
MINIMUM NUMBER OF MODES AT ONE POINT =  1
NUMBER OF WIRE MODES =    3


  4 SEGMENTS ON THE WIRE
```

OUTPUT FOR DESIGN EXAMPLE 2

J	IA(J)	IB(J)	D(J)(M)
1	1	2	0.12500E+00
2	2	3	0.12500E+00
3	3	4	0.12500E+00
4	4	5	0.12500E+00

LISTING OF LOADS AND GENERATORS

0.1000E+01 0.0000E+00 VOLTS BY PT. A OF SEGMENT 3

NWR = NUMBER OF WIRE MODES = 3
NPLTM = NUMBER OF PLATE MODES = 0
NAT = NUMBER OF ATTACHMENT MODES = 0

LOWER TRIANGULAR PART OF SYMMETRIC IMPEDANCE MATRIX

I	J	Z(I,J)	
1	1	0.13429E+02	-0.44815E+03
2	1	0.12639E+02	0.31850E+03
3	1	0.10464E+02	0.37569E+02
2	2	0.13429E+02	-0.44815E+03
3	2	0.12639E+02	0.31850E+03
3	3	0.13429E+02	-0.44815E+03

INPUT ADMITTANCE(MHOS) = 0.009790 J -0.004982
INPUT IMPEDANCE(OHMS) = 81.132 J 41.285
EFFICIENCY(PERCENT) = 100.000

CPU RUN TIME FOR RUN 1 GEOMETRY 1 = 0.49 SECONDS

TOTAL CPU RUN TIME = 0.57 SECONDS

APPENDIX C

OUTPUT FOR DESIGN EXAMPLE 3

```
     INPUT DATA

FREQ.(MHZ) =    300.000   WAVE(M) =      1.000   WIRE RADIUS(M) =  0.0010000
INTP=  10   INTO=  18   INT =     4

WIRE CONDUCTIVITY = -1.00 MEGAMHOS/M


GEOMETRY FOR THE    2 PLATES


                         PLATE NUMBER   1
NM12 =  4    NM23 =  2    IP = 3
X,Y,Z COOR.(METERS) OF CORNER 1 =     0.000     0.000     0.000
X,Y,Z COOR.(METERS) OF CORNER 2 =     0.000     0.000     1.000
X,Y,Z COOR.(METERS) OF CORNER 3 =     0.500     0.000     1.000

COOR.(METERS) OF  10 MODES ON THIS PLATE


                         PLATE NUMBER   2
NM12 =  4    NM23 =  2    IP = 3
X,Y,Z COOR.(METERS) OF CORNER 1 =     0.000     0.000     0.000
X,Y,Z COOR.(METERS) OF CORNER 2 =     0.000     0.000     1.000
X,Y,Z COOR.(METERS) OF CORNER 3 =     0.000     0.500     1.000

COOR.(METERS) OF  10 MODES ON THIS PLATE


COOR.(METERS) OF   4 OVERLAP MODES BETWEEN PLATE  1, SIDE 1 AND PLATE  2, SIDE 1
```

LISTING OF LOADS AND GENERATORS

NWR = NUMBER OF WIRE MODES = 0
NPLTM = NUMBER OF PLATE MODES = 24
NAT = NUMBER OF ATTACHMENT MODES = 0

BACKSCATTERING, ISCAT = 1

		**** CROSS SECTION (DB/WAVE**2) ****				******** PHASE (DEG) ********			
THETA(DEG)	PHI(DEG)	STTM	SPPM	STPM	SPTM	STTM	SPPM	STPM	SPTM
90.0	0.0	-5.316	5.238	-55.855	-55.855	-137.92	-73.44	-90.66	-90.66
90.0	5.0	-9.530	5.930	-73.773	-73.785	-104.13	-62.98	35.67	35.70
90.0	10.0	-11.416	6.265	-76.069	-76.067	-26.17	-53.99	19.33	19.32
90.0	15.0	-4.948	6.338	-76.577	-76.594	24.37	-45.55	-3.82	-3.87
90.0	20.0	-0.157	6.193	-75.712	-75.716	43.76	-40.74	-20.12	-20.12
90.0	25.0	3.041	5.830	-75.168	-75.165	55.23	-36.58	-28.31	-28.30
90.0	30.0	5.226	5.509	-75.687	-75.639	62.90	-33.96	-33.16	-33.13
90.0	35.0	6.666	5.142	-77.746	-77.735	67.33	-32.58	-38.87	-38.90
90.0	40.0	7.491	4.978	-82.193	-82.194	70.34	-32.03	-53.94	-53.85
90.0	45.0	7.760	4.792	-87.102	-87.105	71.31	-31.93	-117.79	-117.90
90.0	50.0	7.491	4.877	-81.086	-81.080	70.34	-32.03	-170.44	-170.42
90.0	55.0	6.666	5.140	-76.902	-76.905	68.30	-32.58	177.87	177.87
90.0	60.0	5.225	5.507	-74.874	-74.880	62.31	-33.96	175.03	175.03
90.0	65.0	3.039	5.887	-74.149	-74.148	55.24	-35.59	176.92	176.91
90.0	70.0	-0.161	6.190	-74.135	-74.139	43.79	-40.75	-175.75	-175.75
90.0	75.0	-4.957	6.335	-74.012	-74.018	24.38	-45.56	-162.25	-162.28
90.0	80.0	-11.427	6.262	-72.881	-72.880	-26.28	-54.00	-147.03	-147.05
90.0	85.0	-9.516	5.927	-70.912	-70.919	-104.20	-62.99	-137.37	-137.38
90.0	90.0	-5.304	5.294	-59.861	-59.860	-137.40	-73.41	95.25	95.26
90.0	95.0	-3.013	4.329	-67.300	-67.301	-158.38	-85.30	-137.26	-137.26
90.0	100.0	-1.833	2.983	-66.137	-66.138	-176.77	-98.61	-142.81	-142.82
90.0	105.0	-1.292	1.184	-65.401	-65.402	164.77	-113.66	-150.22	-150.22
90.0	110.0	-1.107	-1.183	-65.044	-65.046	145.57	-131.38	-158.66	-158.66
90.0	115.0	-1.071	-4.265	-65.020	-65.017	125.71	-154.36	-167.55	-167.55
90.0	120.0	-1.022	-7.836	-65.285	-65.283	105.38	170.13	-176.50	-176.49
90.0	125.0	-0.344	-9.172	-65.803	-65.809	84.21	116.11	174.92	174.92
90.0	130.0	-0.483	-6.556	-65.572	-65.570	63.62	71.57	167.01	167.02
90.0	135.0	0.034	-3.570	-67.556	-67.558	43.71	45.03	160.13	160.13
90.0	140.0	0.723	-1.218	-68.773	-68.770	24.54	26.55	154.64	154.66
90.0	145.0	1.468	0.620	-70.315	-70.313	6.40	11.94	151.21	151.22
90.0	150.0	2.234	2.092	-72.242	-72.244	-11.16	-1.22	151.24	151.24
90.0	155.0	2.972	3.284	-74.613	-74.610	-28.15	-13.39	158.37	158.37
90.0	160.0	3.641	4.231	-76.585	-76.535	-44.67	-25.17	173.80	173.75
90.0	165.0	4.204	4.932	-75.492	-75.485	-60.72	-35.86	-150.01	-150.01
90.0	170.0	4.625	5.368	-72.093	-72.100	-75.27	-49.66	-133.67	-133.68
90.0	175.0	4.871	5.503	-68.913	-68.921	-91.27	-59.76	-129.66	-129.66

OUTPUT FOR DESIGN EXAMPLE 3

90.0	180.0	4.908	5.290	-69.115	-69.117	-105.68	-73.42	165.48	165.48
90.0	185.0	4.705	4.713	-64.549	-64.549	-119.47	-87.15	-134.85	-134.85
90.0	190.0	4.236	3.736	-63.248	-63.249	-132.67	-102.77	-139.46	-139.45
90.0	195.0	3.485	2.466	-62.482	-62.482	-145.33	-121.76	-144.12	-144.12
90.0	200.0	2.463	1.297	-62.254	-62.255	-157.73	-145.55	-148.35	-148.35
90.0	205.0	1.231	0.949	-62.608	-62.608	-170.07	-172.48	-151.72	-151.71
90.0	210.0	-0.058	1.645	-63.637	-63.639	177.41	163.94	-153.84	-153.83
90.0	215.0	-1.210	2.708	-65.535	-65.535	166.66	148.00	-154.06	-154.07
90.0	220.0	-1.966	3.509	-68.718	-68.719	159.37	139.34	-150.89	-150.90
90.0	225.0	-2.224	3.795	-74.270	-74.272	155.26	136.62	-137.80	-137.81
90.0	230.0	-1.967	3.509	-81.079	-81.073	158.35	139.33	-67.51	-67.55
90.0	235.0	-1.213	2.708	-74.343	-74.345	166.61	147.99	-8.80	-8.78
90.0	240.0	-0.074	1.645	-70.249	-70.250	177.75	163.92	5.16	5.18
90.0	245.0	1.224	0.948	-68.369	-68.368	-170.11	-172.50	12.87	12.88
90.0	250.0	2.454	1.294	-67.807	-67.805	-157.82	-145.58	19.12	19.12
90.0	255.0	3.475	2.462	-68.256	-68.258	-145.40	-121.78	24.75	24.76
90.0	260.0	4.226	3.732	-69.675	-69.673	-132.67	-102.78	29.46	29.46
90.0	265.0	4.676	4.709	-72.198	-72.199	-119.45	-87.16	31.69	31.69
90.0	270.0	4.900	5.297	-60.754	-60.753	-105.65	-73.45	-77.95	-77.95
90.0	275.0	4.864	5.500	-80.612	-80.608	-91.23	-60.77	-5.76	-5.72
90.0	280.0	4.620	5.365	-78.573	-78.576	-76.21	-48.67	-50.48	-50.48
90.0	285.0	4.200	4.923	-74.687	-74.685	-60.65	-35.87	-62.35	-62.34
90.0	290.0	3.640	4.229	-72.108	-72.110	-44.59	-25.18	-61.56	-61.56
90.0	295.0	2.974	3.282	-70.440	-70.440	-28.08	-13.40	-56.91	-56.91
90.0	300.0	2.240	2.089	-69.299	-69.299	-11.08	-1.22	-50.89	-50.90
90.0	305.0	1.478	0.617	-68.467	-68.469	6.47	11.84	-44.04	-44.05
90.0	310.0	0.736	-1.221	-67.807	-67.806	24.70	26.65	-36.80	-36.81
90.0	315.0	0.069	-3.574	-67.253	-67.252	43.73	45.04	-29.08	-29.09
90.0	320.0	-0.467	-6.560	-66.783	-66.785	63.51	71.59	-20.77	-20.78
90.0	325.0	-0.929	-9.174	-66.420	-66.420	84.17	116.17	-11.89	-11.89
90.0	330.0	-1.011	-7.832	-66.196	-66.198	105.02	170.17	-2.54	-2.54
90.0	335.0	-1.064	-4.260	-66.168	-66.170	125.63	-154.34	7.08	7.08
90.0	340.0	-1.104	-1.179	-66.391	-66.393	145.58	-131.36	16.57	16.58
90.0	345.0	-1.294	1.188	-66.927	-66.923	164.70	-113.65	25.55	25.56
90.0	350.0	-1.838	2.986	-67.863	-67.863	-176.85	-39.60	33.37	33.36
90.0	355.0	-3.021	4.332	-69.284	-69.284	-158.33	-95.29	33.05	33.05
90.0	360.0	-5.316	5.313	-70.542	-70.540	-137.42	-73.48	-59.29	-59.31

CPU RUN TIME FOR RUN 1 GEOMETRY 1 = 204.88 SECONDS

TOTAL CPU RUN TIME = 205.09 SECONDS

APPENDIX O

OUTPUT FOR DESIGN EXAMPLE 4

```
      INPUT DATA

FREC.(MHZ) =   300.000   WAVE(M) =      1.000   WIRE RADIUS(M) =  0.0010000
INTP=  10   INTD=  18   INT =    4


WIRE CONDUCTIVITY = -1.00 MEGAMHOS/M


GEOMETRY FOR THE   2 PLATES


                  PLATE NUMBER   1
NM12 =  4   NM23 =  2   IP = 3
X,Y,Z COOR.(METERS) OF CORNER 1 =     0.000     0.000     0.000
X,Y,Z COOR.(METERS) OF CORNER 2 =     0.000     0.000     1.000
X,Y,Z COOR.(METERS) OF CORNER 3 =     0.500     0.000     1.000

COOR.(METERS) OF  10 MODES ON THIS PLATE


                  PLATE NUMBER   2
NM12 =  4   NM23 =  2   IP = 3
X,Y,Z COOR.(METERS) OF CORNER 1 =     0.000     0.000     0.000
X,Y,Z COOR.(METERS) OF CORNER 2 =     0.000     0.000     1.000
X,Y,Z COOR.(METERS) OF CORNER 3 =     0.000     0.500     1.000

COOR.(METERS) OF  10 MODES ON THIS PLATE


COOR.(METERS) OF   4 OVERLAP MODES BETWEEN PLATE  1, SIDE 1 AND PLATE  2, SIDE 1
```

LISTING OF LOADS AND GENERATORS

NWR = NUMBER OF WIRE MODES = 0
NPLTM = NUMBER OF PLATE MODES = 24
NAT = NUMBER OF ATTACHMENT MODES = 0

BISTATIC SCATTERING, ISCAT = 2
THETA INC.(DEG.) = 90.0
PHI INC.(DEG.) = 45.0

		**** CROSS SECTION (DB/WAVE**2) ****				******* PHASE (DEG) *******			
THETA(DEG)	PHI(DEG)	STTM	SPPM	STPM	SPTM	STTM	SPPM	STPM	SPTM
90.0	0.0	1.478	1.831	-64.444	-57.147	33.51	-66.59	-49.53	-14.51
90.0	5.0	2.800	2.396	-64.535	-73.196	41.41	-59.33	-45.28	148.86
90.0	10.0	3.963	2.922	-64.873	-73.437	48.45	-52.93	-41.31	154.41
90.0	15.0	4.971	3.396	-65.515	-74.030	54.61	-47.38	-37.77	159.73
90.0	20.0	5.823	3.809	-66.507	-74.940	59.45	-42.67	-34.84	165.00
90.0	25.0	6.520	4.154	-67.960	-76.240	64.17	-38.80	-32.76	170.54
90.0	30.0	7.063	4.427	-70.079	-78.067	67.55	-35.79	-31.38	177.09
90.0	35.0	7.450	4.624	-73.303	-80.614	69.97	-33.63	-33.67	-173.54
90.0	40.0	7.683	4.742	-78.873	-84.062	71.42	-32.33	-43.26	-156.09
90.0	45.0	7.760	4.782	-87.102	-87.105	71.91	-31.90	-117.79	-117.90
90.0	50.0	7.683	4.742	-78.039	-85.303	71.42	-32.33	-179.42	-73.56
90.0	55.0	7.450	4.623	-72.783	-81.762	69.97	-33.63	170.60	-53.18
90.0	60.0	7.062	4.425	-69.673	-79.050	67.55	-35.79	166.10	-45.39
90.0	65.0	6.520	4.152	-67.596	-77.128	64.19	-38.81	162.73	-42.80
90.0	70.0	5.822	3.907	-66.151	-75.776	59.86	-42.68	159.53	-42.97
90.0	75.0	4.970	3.394	-65.152	-74.845	54.62	-47.39	156.25	-44.65
90.0	80.0	3.962	2.920	-64.492	-74.243	48.46	-52.94	152.89	-47.69
90.0	85.0	2.798	2.394	-64.110	-73.908	41.42	-59.35	147.22	-51.75
90.0	90.0	1.476	1.823	-63.965	-60.176	33.52	-66.65	145.63	170.00
90.0	95.0	-0.007	1.240	-64.024	-73.854	24.80	-74.73	142.93	-62.48
90.0	100.0	-1.654	0.649	-64.267	-74.066	15.34	-83.72	138.72	-69.08
90.0	105.0	-3.470	0.083	-64.571	-74.393	5.25	-93.57	135.85	-75.51
90.0	110.0	-5.465	-0.430	-65.207	-74.798	-5.22	-104.22	133.72	-84.82
90.0	115.0	-7.659	-0.855	-65.842	-75.236	-15.61	-115.58	132.61	-94.01
90.0	120.0	-10.038	-1.165	-66.509	-75.661	-24.77	-127.46	132.84	-104.17
90.0	125.0	-12.603	-1.338	-67.114	-76.014	-31.42	-139.65	134.59	-115.24
90.0	130.0	-15.038	-1.367	-67.538	-76.235	-31.45	-151.87	137.74	-127.05
90.0	135.0	-16.512	-1.262	-67.674	-76.282	-22.03	-163.88	141.66	-139.29
90.0	140.0	-15.559	-1.043	-67.489	-76.139	-10.31	-175.47	145.38	-151.56
90.0	145.0	-13.056	-0.738	-67.043	-75.823	-6.30	173.49	147.97	-163.46
90.0	150.0	-10.319	-0.376	-66.459	-75.378	-10.95	163.07	148.96	-174.67
90.0	155.0	-7.773	0.017	-65.838	-74.858	-18.68	153.28	148.36	174.97

OUTPUT FOR DESIGN EXAMPLE 4

90.0	160.0	-5.474	0.418	-65.276	-74.323	-27.88	144.12	146.39	165.49
90.0	165.0	-3.406	0.811	-64.825	-73.818	-37.44	135.56	143.36	156.90
90.0	170.0	-1.544	1.183	-64.520	-73.388	-46.91	127.60	139.55	149.13
90.0	175.0	0.127	1.525	-64.385	-73.062	-55.73	120.21	135.19	142.12
90.0	180.0	1.622	1.837	-64.447	-63.430	-64.02	113.38	130.52	89.57
90.0	185.0	2.949	2.099	-64.724	-72.837	-71.59	107.20	125.48	130.29
90.0	190.0	4.113	2.327	-65.253	-72.930	-79.37	101.60	120.25	125.47
90.0	195.0	5.119	2.516	-66.093	-73.359	-84.33	96.65	114.72	121.40
90.0	200.0	5.968	2.669	-67.313	-73.385	-89.43	92.37	108.63	118.15
90.0	205.0	6.662	2.787	-69.031	-74.315	-93.63	88.80	101.30	115.82
90.0	210.0	7.201	2.875	-71.412	-76.235	-96.33	85.99	90.98	114.59
90.0	215.0	7.586	2.935	-74.581	-79.072	-99.20	83.93	72.80	114.78
90.0	220.0	7.817	2.970	-77.315	-80.672	-100.72	82.71	36.00	117.25
90.0	225.0	7.874	2.981	-75.775	-84.562	-101.19	82.29	-7.24	124.62
90.0	230.0	7.816	2.969	-72.364	-90.787	-100.71	82.71	-29.36	150.55
90.0	235.0	7.585	2.934	-69.612	-91.387	-99.29	83.94	-38.88	-129.68
90.0	240.0	7.199	2.874	-67.602	-85.309	-96.92	85.98	-43.03	-96.22
90.0	245.0	6.659	2.786	-66.151	-82.212	-93.62	88.79	-44.42	-84.76
90.0	250.0	5.965	2.667	-65.125	-79.729	-89.41	92.36	-44.14	-77.52
90.0	255.0	5.116	2.514	-64.437	-78.448	-84.31	96.63	-42.71	-71.28
90.0	260.0	4.110	2.325	-64.037	-77.522	-78.35	101.59	-40.47	-65.06
90.0	265.0	2.945	2.097	-63.885	-76.934	-71.55	107.18	-37.63	-58.46
90.0	270.0	1.618	1.827	-63.964	-58.024	-63.38	113.40	-34.43	-102.52
90.0	275.0	0.123	1.522	-64.256	-76.815	-55.67	120.20	-31.01	-43.28
90.0	280.0	-1.549	1.180	-64.753	-77.050	-46.75	127.58	-27.66	-34.31
90.0	285.0	-3.409	0.808	-65.463	-77.427	-37.35	135.55	-24.67	-24.19
90.0	290.0	-5.476	0.415	-66.399	-77.879	-27.77	144.11	-22.44	-12.67
90.0	295.0	-7.773	0.014	-67.506	-78.313	-18.55	153.27	-21.54	0.36
90.0	300.0	-10.316	-0.379	-68.780	-79.623	-10.79	163.07	-22.82	14.76
90.0	305.0	-13.050	-0.741	-70.078	-78.709	-6.70	173.49	-27.33	30.12
90.0	310.0	-15.555	-1.045	-71.093	-79.434	-10.06	-175.46	-35.79	45.61
90.0	315.0	-16.515	-1.264	-71.403	-77.933	-21.79	-163.87	-47.01	60.43
90.0	320.0	-15.105	-1.369	-70.840	-77.319	-31.27	-151.86	-57.47	73.97
90.0	325.0	-12.607	-1.338	-69.723	-76.528	-31.30	-139.63	-64.29	86.05
90.0	330.0	-10.038	-1.165	-68.462	-75.734	-24.30	-127.44	-67.19	96.78
90.0	335.0	-7.648	-0.855	-67.290	-74.935	-15.56	-115.55	-67.16	106.34
90.0	340.0	-5.462	-0.428	-66.293	-74.320	-5.19	-104.20	-65.19	114.95
90.0	345.0	-3.467	0.085	-65.515	-73.769	5.26	-93.55	-62.01	122.80
90.0	350.0	-1.651	0.652	-64.944	-73.352	15.34	-83.70	-58.12	130.03
90.0	355.0	-0.004	1.243	-64.583	-73.039	24.90	-74.71	-53.88	136.73
90.0	360.0	1.478	1.838	-64.443	-74.358	33.51	-66.54	-49.60	5.30

CPU RUN TIME FOR RUN 1 GEOMETRY 1 = 208.12 SECONDS

TOTAL CPU RUN TIME = 208.33 SECONDS

APPENDIX E

OUTPUT FOR DESIGN EXAMPLE 5

```
      INPUT DATA

FREQ.(MHZ) =   300.000   WAVE(M) =      1.000   WIRE RADIUS(M) =  0.0010000
INTP=  10   INTO=  18   INT =    4

WIRE CONDUCTIVITY = -1.00 MEGAMHOS/M


GEOMETRY FOR THE    3 PLATES


                               PLATE NUMBER   1
NM12 =  4    NM23 =  4    IP = 3
X,Y,Z COOR.(METERS) OF CORNER 1 =     0.500    -0.500    -1.000
X,Y,Z COOR.(METERS) OF CORNER 2 =     0.500    -0.500     0.000
X,Y,Z COOR.(METERS) OF CORNER 3 =    -0.500    -0.500     0.000

COOR.(METERS) OF  24 MODES ON THIS PLATE



                               PLATE NUMBER   2
NM12 =  4    NM23 =  4    IP = 3
X,Y,Z COOR.(METERS) OF CORNER 1 =     0.500    -0.500     0.000
X,Y,Z COOR.(METERS) OF CORNER 2 =     0.500     0.500     0.000
X,Y,Z COOR.(METERS) OF CORNER 3 =    -0.500     0.500     0.000

COOR.(METERS) OF  24 MODES ON THIS PLATE
```

```
                        PLATE NUMBER   3
 NM12 =  2   NM23 =  4   IP = 3
X,Y,Z COOR.(METERS) OF CORNER 1 =     0.250     0.500     0.000
X,Y,Z COOR.(METERS) OF CORNER 2 =    -0.250     0.500     0.000
X,Y,Z COOR.(METERS) OF CORNER 3 =    -0.250     0.500     1.000

 COOR.(METERS) OF  10 MOOES ON THIS PLATE


 COOR.(METERS) OF   4 OVERLAP MOOES BETWEEN PLATE  1, SIOE 2 ANO PLATE  2, SIOE 4


 COOR.(METERS) OF   2 OVERLAP MODES BETWEEN PLATE  2, SIDE 2 ANO PLATE  3, SIOE 1




    3 POINTS ON THE WIRE
  I         X (I)          Y (1)          Z (1)

  1   0.0000E+00     0.0000E+00     0.0000E+00
  2   0.0000E+00     0.0000E+00     0.1250E+00
  3   0.0000E+00     0.0000E+00     0.2500E+00


  MOOES ON THE WIRE STRUCTURE

  MAXIMUM NUMBER OF MODES AT ONE POINT =  1
  MINIMUM NUMBER OF MODES AT ONE POINT =  1
  NUMBER OF WIRE MOOES =   1



    2 SEGMENTS ON THE WIRE
  J    1A(J)   1B(J)    O(J)(M)

  1      1       2     0.12500E+00
  2      2       3     0.12500E+00



 GEOMETRY FOR THE  1 ATTACHMENT POINTS

 I  SEGMENT  ENO  PLATE       B(M)
```

```
   1      1      0      2     0.20000

     LISTING OF LOADS AND GENERATORS

      0.1000E+01   0.0000E+00 VOLTS AT ATTACHMENT  1


     NWR = NUMBER OF WIRE MODES =    1
     NPLTM = NUMBER OF PLATE MODES =   64
     NAT = NUMBER OF ATTACHMENT MODES =    1


   INPUT ADMITTANCE(MHOS) =   0.021195 J  -0.003203
   INPUT IMPEDANCE(OHMS) =     46.127 J      6.971
   EFFICIENCY(PERCENT) = 100.000


   CPU RUN TIME FOR RUN   1 GEOMETRY   1 =      411.84 SECONDS


         INPUT DATA

   FREQ.(MHZ) =   300.000   WAVE(M) =     1.000   WIRE RADIUS(M) =  0.0010000
   INTP=  10   INTD=  18   INT =    4


   WIRE CONDUCTIVITY = -1.00 MEGAMHOS/M


   GEOMETRY FOR THE   3 PLATES


                       PLATE NUMBER   1
   NM12 =  4    NM23 =  4    IP = 3
  X,Y,Z COOR.(METERS) OF CORNER 1 =     0.500    -0.500    -1.000
  X,Y,Z COOR.(METERS) OF CORNER 2 =     0.500    -0.500     0.000
  X,Y,Z COOR.(METERS) OF CORNER 3 =    -0.500    -0.500     0.000

   COOR.(METERS) OF  24 MODES ON THIS PLATE



                       PLATE NUMBER   2
   NM12 =  4    NM23 =  4    IP = 3
  X,Y,Z COOR.(METERS) OF CORNER 1 =     0.500    -0.500     0.000
  X,Y,Z COOR.(METERS) OF CORNER 2 =     0.500     0.500     0.000
  X,Y,Z COOR.(METERS) OF CORNER 3 =    -0.500     0.500     0.000
```

```
COOR.(METERS) OF  24 MODES ON THIS PLATE



                         PLATE NUMBER   3
 NM12 =  2   NM23 =  4   IP = 3
X,Y,Z COOR.(METERS) OF CORNER 1 =     0.250     0.500     0.000
X,Y,Z COOR.(METERS) OF CORNER 2 =    -0.250     0.500     0.000
X,Y,Z COOR.(METERS) OF CORNER 3 =    -0.250     0.500     1.000

COOR.(METERS) OF  10 MODES ON THIS PLATE


COOR.(METERS) OF   4 OVERLAP MODES BETWEEN PLATE  1, SIDE 2 AND PLATE  2, SIDE 4


COOR.(METERS) OF   2 OVERLAP MODES BETWEEN PLATE  2, SIDE 2 AND PLATE  3, SIDE 1



   3 POINTS ON THE WIRE
 I        X (I)          Y (I)          Z (I)

 1   0.0000E+00     0.3000E+00     0.0000E+00
 2   0.0000E+00     0.3000E+00     0.1250E+00
 3   0.0000E+00     0.3000E+00     0.2500E+00


 MODES ON THE WIRE STRUCTURE

 MAXIMUM NUMBER OF MODES AT ONE POINT =  1
 MINIMUM NUMBER OF MODES AT ONE POINT =  1
 NUMBER OF WIRE MODES =   1


   2 SEGMENTS ON THE WIRE
 J    IA(J)    IB(J)     D(J)(M)

 1      1        2     0.12500E+00
 2      2        3     0.12500E+00
```

```
GEOMETRY FOR THE  1 ATTACHMENT POINTS

I  SEGMENT  END  PLATE      B(M)

1     1      0      2     0.20000

  LISTING OF LOADS AND GENERATORS

   0.1000E+01   0.0000E+00 VOLTS AT ATTACHMENT  1

  NWR = NUMBER OF WIRE MODES =     1
  NPLTM = NUMBER OF PLATE MODES =    64
  NAT = NUMBER OF ATTACHMENT MODES =     1


INPUT ADMITTANCE(MHOS) =    0.013087 J  -0.014962
INPUT IMPEDANCE(OHMS) =      33.121 J     37.866
EFFICIENCY(PERCENT) = 100.000


CPU RUN TIME FOR RUN   1 GEOMETRY   2 =       94.19 SECONDS


TOTAL CPU RUN TIME =       506.23 SECONDS
```

DATE

ILME